Annual Report 1957

National Bureau of Standards

U. S. Department of Commerce

UNITED STATES DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
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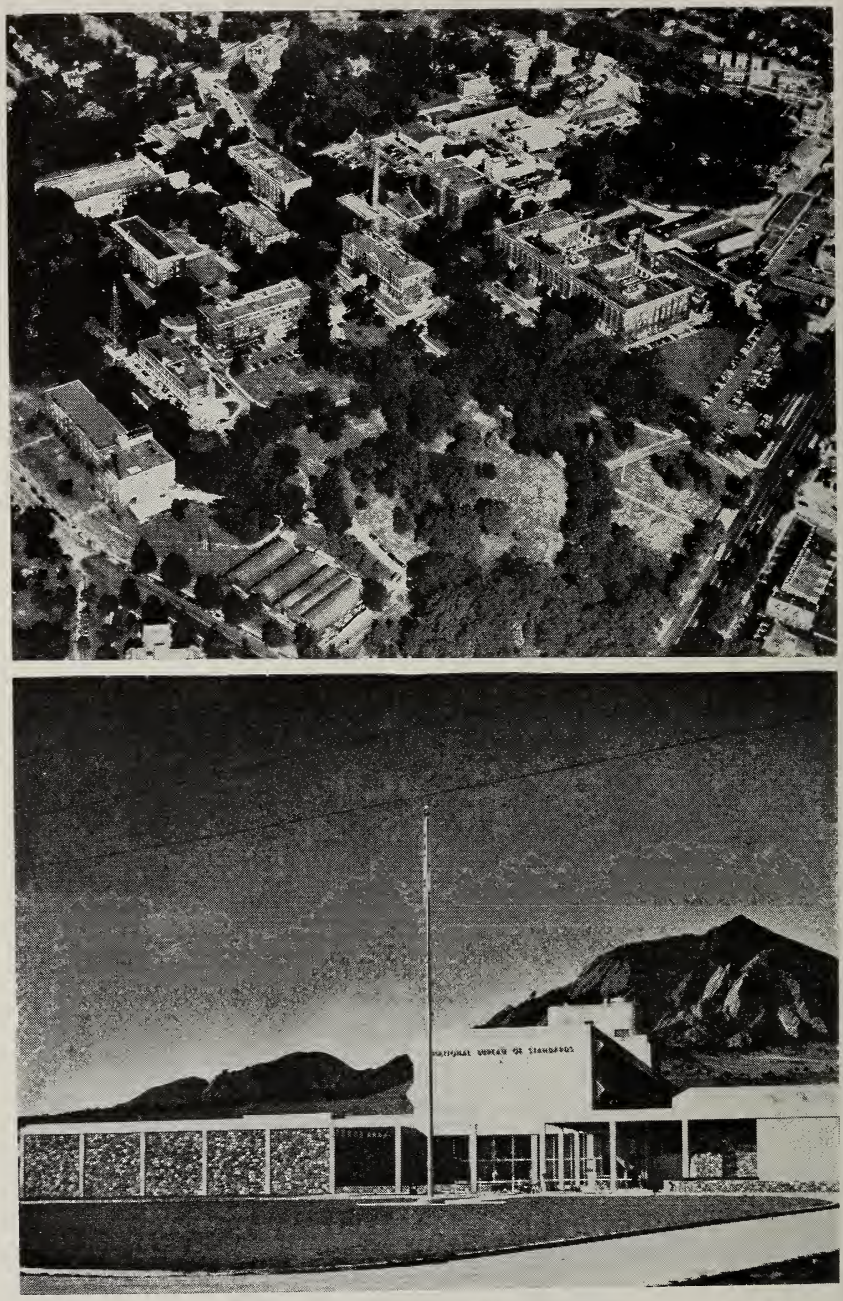

The National Bureau of Standards, Washington, D. C. laboratories (top) and Boulder, Colorado, laboratories (bottom).

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1. General Review

1.1. Introduction

The establishment of new and better standards of physical measurement and the development of techniques and instruments for using these standards throughout the Nation are the primary concerns of the National Bureau of Standards. Advancement in measurement is fundamental to technological progress and to scientific growth.

To fulfill its principal responsibilities, the Bureau must conduct an imaginative and vigorous research and development program in the physical and engineering sciences. This report reviews the Bureau's work for the past year and presents some of the more significant achievements resulting from the work. Standards and measurement are fields of dynamic research interest. There are literally hundreds of physical standards, and there is a continuous search for new ones. Every major scientific advance must be preceded and followed by new standards and measurement techniques and associated standards.

Precision measurement almost always precedes important developments in the experimental sciences. In fact, the precisions achieved in measurement may well be considered as indicators of the stage of progress in a particular experimental science. Greater accuracies in experimental data enable, in many cases, the reconciliation of conflicting research theories and the advancement to "discovery" which is so significant in the opening of new areas of scientific investigation.

The effort devoted to the measurement sciences, therefore, should be consistent with need for newer and more refined techniques and instrumentation. In the past decade, research, in both public and private laboratories, has expanded at a rapid rate. The requirement for finer tolerances in our production industries has also become more pressing. New areas of scientific and industrial development have been opened up, each requiring new data on the basic properties of materials, new standards as reference points in making systematic progress, and new methods of measurement which are reliably related to the whole chain of standards and physical constants.

The National Bureau of Standards is conscious of its responsibilities to these new areas of science and technology. In many of these areas, professional members of the Bureau's staff are conducting important pioneering research studies in order to produce the critical measurement data required. Within the limits of its budget, and with the cooperation of other scientific organizations throughout the country, the Bureau is following a course of increased concentrated activity in the field of measurement research.

1.2. Technical Activities

Standards and Measurement. As in previous years, the Bureau's principal activity was the development and improvement of standards and methods of physical measurement. For example, intensive research was carried on at the Boulder Laboratories to establish atomic standards of frequency and time. Based on an unchanging property of the atom, such standards would have significant advantages over the present standard—the rotating earth. Because the earth's rotation about its axis is subject to irregular variations and at the same time is gradually slowing down, it has been replaced by international agreement by a specific period of its rotation about the sun (the topical year 1900) as the basis for our standard of time. This action was considered an interim step preceding the final development of an atomic standard as more stable, accurate, and dependable. During the past year, both a cesium-beam spectrometer and an ammonia-beam spectrometer were put into operation as potential atomic standards with a precision of 1 part in 1 billion. The precision was limited to this value by the instability of the quartz-crystal oscillators associated with the two instruments.

Standard frequencies based on the rotating earth are now available at the Boulder Laboratories to an accuracy of 1 part in 100 million and a constancy better than 1 part in 1 billion. However, it is expected that science and industry will soon require even more rigorous tolerances. To meet this situation, research on the stability of quartz-crystal oscillators was intensified. Preliminary results indicated that a substantial reduction in frequency aging and frequency drift with temperature may be obtained by reducing the temperature of the crystal.

Work on improved standards covered a variety of fields. To increase the accuracy of the present temperature scale, a photoelectric pyrometer was developed for measurement of high temperatures; preliminary studies indicate that a precision of 0.1 deg C at 2,000° C is attainable. Progress was made in designing a re-entrant type of ionization chamber for calibration of small radium and cobalt-60 sources. Such a chamber should appreciably reduce measurement time and exposure of operating personnel to radiation. The microcalorimeter for the calibration of bolometer mounts in waveguide systems was refined to such a point that it is now possible to calibrate these mounts with an accuracy of 1 percent or better.

A special technique was devised for very-high-intensity calibration of microphones used to measure sound intensities in the vicinity of jet aircraft. Under the sponsorship of the Army Ordnance Corps, construction was begun on an improved pressure measuring device for dynamic calibration at high pressures. Work continued under Air Force sponsorship on a new pressure standard for calibration of high-altitude instruments. A standard hygrometer was designed for measuring the humidity of gases. Part I of a new edition of Handbook H28, *Screw-Thread Standards for Federal Services*, was completed and prepared for publication. Progress was made in developing color standards for dental materials.

At the request of the Joint Electron Tube Engineering Council, the Bureau developed light standards of red, green, and blue for color television tubes.

An absolute determination of the ampere in terms of the mechanical units of length, mass, and time was completed, using the modified Rayleigh type of current balance last used in 1940. The result agreed within 3 parts per million with that obtained last year using a radically different current balance of the Pellat type.

Of considerable potential value to American industry was the development of an interferometer that compares lengths to the nearest 10-millionth of an inch. This extremely precise instrument will be used to check lengths of industry's master gage blocks which control the tolerances of mass-produced machine parts. An instrument of this accuracy has been greatly needed because of the extremely small dimensional tolerances now required for parts used in the guided-missile, jet-aircraft, machine-tool, and other industries.

At present the Bureau calibrates master gage blocks to an accuracy of 1 part in 1 million, that is, to the nearest millionth of an inch for inch-long blocks. However, the use of continually smaller tolerances in industry has caused machine-tool manufacturers to request that the Bureau develop procedures for calibrating their master gage blocks on a regular basis to 1 part in 10 million. Because of the extreme importance of this work, the Congress has specifically requested increased effort on the project, and 11 major industrial firms have made supplementary funds available so that the necessary research can be carried out as soon as possible.

Objectives of the project are twofold: (1) to develop the necessary instrumentation and methods, and (2) to develop more stable materials for gage blocks so that measured lengths will not change appreciably with time. In connection with the latter phase, the Bureau is now evaluating gage block materials for dimensional stability, wear and corrosion resistance, and thermal expansion. Development of the precise interferometric comparator represents an important step toward the goal of this program. A major problem yet remaining is the development of means for absolute calibration—to the nearest 10-millionth of an inch—of the primary standard gage blocks with which the Bureau compares industry's master gage blocks.

Other fields of measurement continued to be active. In work partially supported by the Office of Naval Research and the Atomic Energy Commission, an instrument was developed that promises to extend electron scattering measurements to a greater precision and range of angles than was previously possible. A method that gives a precision of 1 part in 10 thousand was devised for the coulometric titration of acids and bases. A highly accurate technique for measuring the speed of sound in water was worked out for sonar use by the Navy. In connection with a project sponsored by the U. S. Bureau of Mines, an adiabatic calorimeter providing high precision within the temperature range from 30° to 500° C was

developed for measuring the thermodynamic properties of sulfur. Until now, accurate thermodynamic data on sulfur have been lacking because of the difficulty of calorimetric determinations on a material of such complex behavior.

Advances were also made in analytical techniques. For example, a procedure was devised for determining and controlling the composition of barium titanate ceramic dielectrics, vital to national defense. A rapid yet highly accurate spectrometric method was developed for determining impurities in high-purity gases. With this technique, the impurities in nitrogen, water vapor, and hydrogen can be measured in concentrations as low as 1 part per million and the time required is only 6 seconds per element. Because of its high speed, the method is particularly well adapted for monitoring the composition of a continuously flowing gas. A method was also devised for interpreting the very complex mass spectra of smog samples condensed at the temperature of liquid nitrogen.

Properties of Matter and Materials. Of broad scientific interest was an experiment with polarized atomic nuclei at a temperature near absolute zero. Carried out by Bureau scientists in collaboration with Professor C. S. Wu of Columbia University, this experiment first demonstrated that the quantum mechanical law of parity conservation does not hold in beta decay of radioactive cobalt.[1] This result shattered a fundamental concept of nuclear physics that had been universally accepted for the past 30 years. It thus cleared the way for a reconsideration of current physical theories with the possibility of new, far-reaching discoveries regarding the nature of matter.

In particular, removal of the restrictions imposed by parity conservation promises to bring order to the theoretical chaos now existing in regard to subatomic particles. It is generally held that the new "elementary" particles from proton accelerators are manifestations of the forces that bind the nucleus together. Thus, a better understanding of these particles may well lead to a more fundamental, unifying theory of matter and energy.

Basically, parity conservation in quantum mechanics means that two physical systems, one of which is a mirror image of the other, must behave in identical fashion except for the mirror image effect. In other words, nature is symmetrical and makes no fundamental distinction between right- and left-handed rotations or between the opposite sides of a subatomic particle. Thus, for example, two similar radioactive particles spinning in opposite directions about the same axis should emit the same intensity of radioactivity in any given direction. Neither the right- nor the left-handed rotation should be favored by a greater intensity of emission so long as parity is conserved.

In the experiment at the Bureau, cobalt-60 nuclei were directionally oriented by subjecting them to a magnetic field at low temperature. It

[1] This finding provided experimental verification of the theoretical work of T. D. Lee of Columbia University and C. N. Yang of the Institute for Advanced Study, for which these two scientists received the 1957 Nobel Prize in Physics.

was found that emission of beta particles is greater in one direction along the axis of nuclear spin than along the other. This finding unequivocally demonstrated that parity is not conserved in beta decay of cobalt-60.

Significant progress was made during the year on three projects directed toward a better understanding of the basic interaction of high-energy X-rays with matter. In the first of these projects, which was supported by the Air Research and Development Command, it was found possible to use the scattering of 15-million-volt X-rays to study in detail the shape of the X-ray spectrum from a high-energy electron accelerator. Knowledge of the shape of this spectrum will be of considerable value in interpreting data on nuclear energy levels obtained with betatrons and synchrotrons.

The other two projects, which were supported by the Atomic Energy Commission, have provided information about the structure of the nucleus. In one of these, it was found that study of the photoproduction of π° mesons from carbon leads to information on the distribution of nuclear matter within the carbon nucleus. In the second study, a correlation was found between the photoneutron yield from a given nucleus and the deformation of the nuclear surface.

Experimental studies of high-energy radiation led to a theory which explains the basic features of radiation effects on polymers. Knowledge of these mechanisms suggests new areas of experimental attack which should aid in developing techniques for improving polymeric materials by atomic radiation, and for producing radiation-resistant materials. In another branch of polymer science, infrared absorption studies provided information on the molecular structures resulting from different methods of vulcanizing rubber. Such knowledge is important to an understanding of the physical properties of rubber.

After 5 years of intensive effort, the third volume of *Atomic Energy Levels* (NBS Circular 467) was completed. This compilation contains all available information on energy levels, quantum numbers, magnetic splitting factors, and electron configurations derived from 124 spectra of 32 elements (42 Mo to 57 La, and 72 Hf to 89 Ac). Most of the new information on technetium, ruthenium, iodine, hafnium, tantalum, rhenium, and actinium resulted from research at the Bureau. The results for actinium show that this element introduces, in the seventh period of the periodic chart of the elements, another group of 14 "rare earths" in which f-type electrons are more or less firmly incorporated into the outer structure of the heavier elements, thorium, protactinium, uranium, neptunium, plutonium, etc.

The refractory and light metals, such as titanium and zirconium, have many special properties which make them particularly important to modern industry and the armed services. However, their deposition potentials are so far above hydrogen in the electromotive series that none of them can be deposited from aqueous solutions. For several years the Bureau has been investigating the relatively unexplored field of electrodeposition from organic solutions. During 1957 this work resulted in

the deposition of beryllium, magnesium, titanium-aluminum alloys, and zirconium-aluminum alloys. In addition, improvement was made in a process developed in 1952 for electrodepositing aluminum from organic solutions.

In low-temperature research sponsored by the Atomic Energy Commission, an unusually effective catalyst was developed for converting ortho- to parahydrogen. This catalyst, hydrous ferric oxide, is greatly simplifying the problem of liquid hydrogen storage. The ortho molecules are unstable at low temperatures and gradually change into para molecules, liberating heat energy in the process and causing wasteful evaporation. Before the development of hydrous ferric oxide and other conversion catalysts, the problem of evaporation in storage could be met only by the use of special refrigeration equipment.

Valuable information on the structure and properties of matter may eventually result from a 3-year program of basic research initiated during the year. The object of the program is to increase fundamental knowledge of the formation, properties, and storage of the highly reactive molecular fragments known as free radicals.

Ordinarily free radicals exist only for a very short period in systems such as flames and hot gases. However, within the past 5 years, methods have been developed in a number of laboratories for capturing and storing them, mainly at low temperatures. Such storage techniques now promise to provide an important tool for the study of atomic and molecular physics and for research in basic chemistry. However, before this promise can be realized much additional research must be done on free radicals of all types in order to provide information on their properties in solid, liquid, and gaseous phases; their recombination rates at various temperatures; and their reactions with other materials. The free radicals program was set up to provide an integrated approach to these problems and to stimulate new areas of research in the field.

Financial support of the program is provided by the Department of Defense through the Office of Ordnance Research, U. S. Army.

Data Processing Systems. This program includes research, development, systems design and analysis, and technical advisory services in both digital and analog computer technology. An increasing number of Government agencies are seeking the Bureau's technical advisory services on the use of high-speed digital techniques in new areas of potential application such as massive paperwork operations, control systems, and simulation, as well as in the solution of specific technical problems.

Since 1950, the Bureau's high-speed digital computer SEAC has been operated, mainly on a round-the-clock schedule, to solve a variety of problems in science, engineering, and management. In 1957, however, a more powerful computational machine of advanced design was obtained from a commercial supplier for this purpose, and SEAC was converted into a facility for research on data processing applications and for engineering studies of computer components and systems. Preparation for this

new role was under way throughout the year, involving installation of new input-output circuitry and additional memory equipment.

Included in the new SEAC equipment is an input-output staticizer which makes possible direct communication of SEAC with an analog computer. Thus, the two machines can now be used together in combination with display equipment to simulate complex systems in which human operators comprise serial elements in control loops. Plans call for the use of this combined assembly to simulate the flight of a manned supersonic aircraft with ground control and to provide prompt computation of the data for analysis.

Progress was made in a cooperative program with the Patent Office for the mechanization of patent search operations. The Bureau developed a procedure for use of SEAC in searching topological structures, and applied it to an element-by-element search of chemical structures in steroid patents. A comprehensive machine procedure was also developed for general searches of patents pertaining to the composition of matter.

Under sponsorship of the Rome Air Development Center, automatic scanning equipment was designed that permits a digital computer to accept automatically an image from a photograph or drawing into its memory, and to reproduce a facsimile copy from its memory or to display the image as modified by internal processing. New techniques of mathematics, logic, and linguistics that may be applicable to the solution of complex problems in information retrieval were also explored, and work was done on a machine program to investigate the syntactical structure of a variety of English sentences.

Design specifications were under development for a large-scale pilot data processor that will combine in a single installation a number of different characteristics not ordinarily found in one machine. These include high computation rate, flexibility of communication with external devices, and a wide variety of internal processing operations. A machine of this scope is needed for experimental investigations of such problems as patent searching and the real-time scheduling and control of air traffic. At present, realistic test runs on large-scale data-reduction, record, and information retrieval problems are beyond the capabilities of available equipment.

International Geophysical Year. At the close of the fiscal year, extensive preparations were under way for NBS participation in the International Geophysical Year of 1957–58. During the IGY, which began July 1, 1957, and will continue through December 31, 1958, several thousand scientists representing some 60 nations will make simultaneous worldwide observations of the earth and its immediate cosmic environment. The data gathered in this huge cooperative measurement program should help answer questions regarding the size and shape of the earth, the origins of earthquakes, the causes of radio blackouts, the sources of weather disturbances, and many other earth phenomena.

The United States National Committee for the IGY, organized by the National Academy of Sciences—National Research Council, is planning

and directing U. S. participation in the program, while the National Science Foundation is reponsible for the Government's fiscal sponsorship. The National Bureau of Standards is concerned principally with collecting and analyzing data of upper atmospheric phenomena and radio propagation. Centered in the Boulder Laboratories, where most NBS radio-propagation research is carried on, the Bureau's part in the IGY program involves the active participation of more than 100 staff members.

The greatest part of the Bureau's effort will be concerned with variations in the ionosphere, the electrically charged region of the upper atmosphere 25 to 250 miles above the earth. By reflecting radio waves the ionosphere makes possible long-distance transmission between such points as New York and London. Changes in the various layers of the ionosphere, which may be caused largely by solar activity, greatly affect the quality of long-range reception in different frequency ranges.

Intense ionospheric activity is expected during the IGY period, and IGY scientists hope to gather enough information about the ionosphere so that much improved predictions of radio propagation conditions can be made. Because of its many years of experience in ionospheric studies, the Bureau has been given responsibility for the ionospheric data program in the Western Hemisphere. Altogether it is directly concerned with some 37 of the almost 200 stations scattered throughout the world that will be making vertical soundings of the ionosphere. It is equipping and supplying 19 new stations, carefully located to fill important gaps in the world network. Five of these—the antarctic sounding stations—will be operated by NBS and the others will be closely guided in their work by Bureau staff members. The pre-IGY network of 7 NBS-operated and 11 associated stations will continue through the IGY period. Simultaneous data gathered by all the stations will be plotted and analyzed to provide a global picture of the ionosphere and its properties.

One of the outstanding mysteries in the propagation of radio waves by the ionosphere is the phenomenon known as sporadic *E*. Very high frequencies, such as television and FM signals, ordinarily pass through the ionosphere into space without reflection. Sometimes, however, these signals are reflected spasmodically and erratically back from highly ionized patches in the ionosphere, and are heard over distances of more than 1,000 miles. This phenomenon is called sporadic *E* from its uncertain nature and from the fact that reflection takes place in the *E*-layer of the ionosphere. As part of the IGY program, the Bureau is intensifying its study of sporadic *E*, operating carefully controlled circuits in the Far East, South America, the Caribbean, and the United States. In one experiment, a study is being made of the scattering of radio waves from the lower portion of the *E*-region in the vicinity of the magnetic equator. Another major activity is an experiment to determine the comparative behavior of sporadic *E* ionization in the Eastern and Western Hemispheres.

The Bureau will play an important part in the IGY study of radio noise. Here the objective will be to learn more about radio interference and propagation through the atmosphere and ionosphere. Sixteen worldwide stations for noise observations have been set up in cooperation with other U. S. agencies and other countries. One American noise station is at Byrd Base in Antarctica; others are in Hawaii, Greenland, and the Canal Zone, as well as the continental United States. NBS-equipped stations operated by foreign countries are in South Africa, Ghana, Morocco, Australia, Brazil, Malaya, India, Sweden, and Japan. All data from the various stations will be forwarded to the Boulder Laboratories for analysis.

The results of this study will not only provide valuable information about radio propagation and meteorology but will also establish an engineering basis for assigning frequencies to stations. For the commercial and military radio users who must know which frequencies are best for use at a given time and place, forecasts will be made of the amount of unwanted noise that will interfere with their communications. With other information provided by the Bureau, they will be able to tell the minimum transmitter power than can be used to get their information to the receiver in spite of competition from noise of natural origin.

Another atmospheric phenomenon of interest to IGY scientists is airglow, a faint night-sky luminescence rarely visible to the naked eye. The Bureau will operate two airglow observing stations and has supplied special equipment for airglow observation to others in the American chain of 13 airglow stations which runs from Thule, Greenland, to San Juan, Argentina. It is hoped that the airglow data, when combined with the findings of other upper atmosphere programs, will reveal information about the composition, temperature, and dynamics of the upper atmosphere.

The day-to-day coordination of a large part of IGY observations will be accomplished through the most extensive communication network ever arranged for scientific research purposes. Focal point of the system is the Bureau's radio forecasting center near Washington, which has been selected as the IGY World Warning Agency by the international IGY committee. From this nerve center of the IGY program, located at Fort Belvoir, Virginia, warnings will be flashed to scientists throughout the world to redouble their observational efforts in anticipation of unusual activity in cosmic rays, aurora, earth magnetism, and ionospheric disturbances. With the activation of the IGY World Warning Agency, the telegraphic reporting of significant solar, ionospheric, and related data was increased tenfold at the forecasting center so that all outstanding phenomena of significance for geophysical experiments can now be made known in less than 24 hours.

Calibration, Testing, and Standard Samples. The Bureau insures the accuracy of countless industrial and scientific instruments by comparing the master standards of other laboratories and industry with the national

standards of physical measurement. Such calibration services are vital to industrial and scientific progress, insuring the accuracy of working standards throughout the Nation. Testing, on the other hand, is almost entirely confined to requests from Federal agencies, usually in connection with quantity purchase of materials like cement for Government use. More than 149,000 calibrations and tests were performed in fiscal year 1957.

During the year, improvements in calibration facilities increased both the accuracy and efficiency of the services. For example, a mobile cement-testing laboratory, housed in a trailer, was put into operation to supplement the 5 permanent cement-testing laboratories maintained by the Bureau in various parts of the country. The resistance thermometry laboratory, which maintains the temperature scale from 10 degrees above absolute zero to 630° C, was relocated and modernized, and new equipment was added to improve calibration accuracy and reduce costs. An experimental frequency broadcast was begun, making possible frequency measurements to a precision of 1 part in 1 billion throughout the continental United States.

At the close of the year, housing for the new Electronic Calibration Center at the NBS Boulder Laboratories was virtually completed. The center is being set up to meet the urgent needs of the armed services for accurately calibrated electronic equipment.

Closely related to the calibration program is the work on standard samples of chemicals, metals, and alloys, which are issued to industrial and research laboratories. Standard samples are materials that are certified for chemical composition or for some physical or chemical property, such as heat of combustion, melting point, or index of refraction. They provide bases of comparison so that, for example, the manufacturer of a chemical can control its purity by comparing his product with the standard sample. Standard samples make possible uniform measurements of heat and temperature, define the colors of paints, and calibrate the instruments that control the composition of synthetic rubbers and motor fuels. During 1957 the number of different standard materials available from the Bureau as samples was increased from 575 to 580, and 38,827 individual standard samples were issued. To meet pressing demands in industry, a 3-year program was initiated for the preparation of 150 new spectrometric standard samples, of which 55 were nearing completion at the end of the year.

Cooperative and Consulting Services. The Bureau's advisory and cooperative activities are of considerable value in science, industry, and Government. For example, the Bureau cooperates with state and municipal governments in the field of weights and measures. Here the Bureau has fundamental responsibility for the standards of weights and measures whereas the state and local governments possess regulatory authority for maintenance of uniform procedures. The Bureau contributes to these local bodies the means and methods whereby measurements in commerce may be made in a uniform manner, consistent with the national standards.

Cooperation with other Federal agencies ranges from the supplying of technical information upon request to long-range projects undertaken through various scientific and technical committees. An important area of interagency cooperation is the development and establishment of Federal Specifications. Issued by the General Services Administration, these specifications result in purchase economies by establishing criteria that govern quality and by providing opportunity for all businesses to compete for Federal trade through the bid system. The Bureau has accepted responsibility for preparation and maintenance of 215 Federal Specifications covering a wide range of materials and products. At the request of GSA and other agencies, it reviews approximately 500 proposed specifications each year for technical adequacy and test procedures.

Another phase of technical cooperation, somewhat broader in scope, is the Bureau's participation in the work of national and international societies, associations, and standardizing bodies. During the past year, Bureau staff members held approximately 1,550 positions in groups such as the American Society for Testing Materials, American Standards Association, Institute of Radio Engineers, American Physical Society, International Organization for Standardization, and the International Union of Pure and Applied Chemistry. By participating in these organizations, the Bureau is able to play an active part in bringing new advances of science into the technology of American industry, in developing test methods, in standardizing materials and products for greater economy and improved quality, and in establishing uniform scientific standards throughout the world.

1.3. Administrative Activities

The Bureau's activities are of two major budgetary classes: first, the basic programs which are supported by directed appropriations from the Congress; second, various projects undertaken for other Government agencies with funds transferred from those agencies.

During 1957, the total funds obligated for both areas of activity, including, construction and facilities, were $28,011,000. Of this total, $10,010,000 came from direct Congressional appropriation for the basic program and the remaining $18,001,000 represented programs conducted for other Government agencies and private sources.

During the year the major construction phase of the new wing to house the Electronic Calibration Center at the NBS Boulder Laboratories was completed. This Center is expected to service Defense agencies and other organizations in the calibration of master electronic standards against the Bureau's reference standards. In the coming year, the Center will be equipped and put into operation.

The Bureau's plan to convert some of its staff to basic Bureau activities and to reduce the proportion of the total program devoted to other agency projects is being slowly activated. During the past year, considerable study went into a reexamination of the relationship of Bureau responsibilities to other agency requests. Bureau staff members and technical

advisory committees reviewed the technical programs and made recommendations for strengthening the Bureau's basic research activities. New projects accepted from other agencies now are given a careful screening as to their appropriateness for Bureau research in terms of their relation to Bureau objectives and in terms of the availability of unique Bureau facilities.

During the past year, 12 technical committees were serving the Bureau's scientific program (appendix, page 121). Composed of prominent scientists and industrial representatives, these committees, which supplement the Bureau's Statutory Visiting Committee (appendix, page 121), are a valuable source of consultation and stimulation and serve to bring to the Bureau the views and needs of the Nation's scientists and technologists.

1.4. Publications

The results of the Bureau's technical program are in general embodied in its reports and publications. Even when the work is developmental in nature—for example, the development of a specific device—a report will represent the culmination of the activity, and it is this report that will often prove of most value to Government, science, and industry. The reports and publications of the Bureau are therefore suggestive of the scope of its activities. During the year these totaled over 1,250, exclusive of calibration and test reports and of general administrative documents. Some 650 classified and unclassified reports were issued to other Government agencies, particularly the Department of Defense, while 608 papers and documents were published formally. Of the formal publications, some 450 consisted of scientific and technical papers, 81 of which were published in the *Journal of Research of the National Bureau of Standards* (a monthly periodical) and the remainder in the journals of various professional, engineering, and trade organizations. In addition, 107 summary reports were published in the Bureau's monthly *Technical News Bulletin*. The third monthly periodical of the Bureau, *Basic Radio Propagation Predictions*, each month, for a 1-month period 3 months in advance, presented radio-propagation data needed in determining the best frequencies to use in long-range radio communications.

Twenty-one papers were published in the Bureau's nonperiodical series of publications: 2 in the Applied Mathematics Series, 1 in the Handbook series, 12 in the Circular series, 3 in the Building Materials and Structures Report series, and 3 in the Miscellaneous Publication series.

A list of publications for the fiscal year is given in the appendix, section 5.6 (page 127).

2. Research and Development Program

The Bureau's technical program is carried out through organizational units called Divisions. These are shown in appendix 5.1. The review of the research and development programs is presented in this section under headings corresponding generally to these organizational units.

2.1. Electricity and Electronics

The work in electricity is primarily the development, improvement, and dissemination of the standards of measurement for electrical quantities, and the study of the properties of materials that are important in all applications of electricity and magnetism. The object is to provide electrical standards that are, as far as possible, constant over long periods of time, uniform throughout the Nation, and consistent with the fundamental mechanical units. The work includes the dissemination of standards of electrical resistance, inductance, capacitance, dielectric constant and loss, electromotive force, current, power, energy, magnetizing force, and magnetic induction.

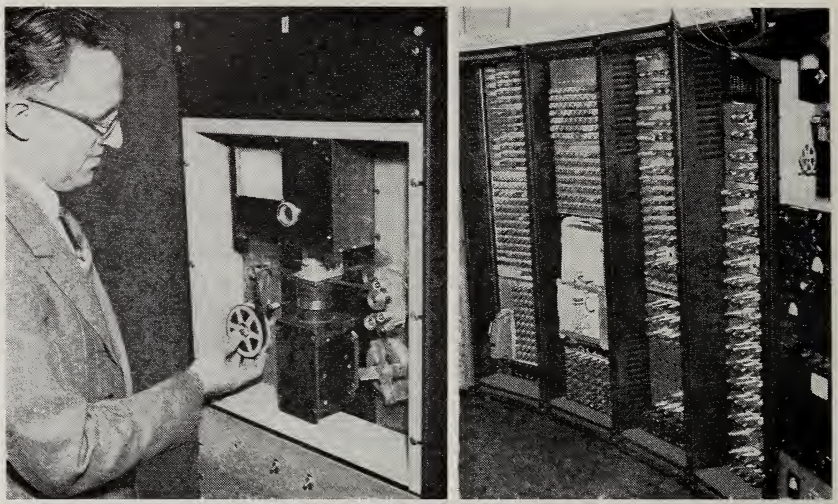
The electronic activities include the standardization of test methods for electronic components, the study of materials and processes for component fabrication, and the establishment of optimum designs of electronic equipment for maximum life and reliability. In areas where the Bureau is uniquely qualified, electronic development programs are undertaken to meet the special requirements of NBS and of other Governmental agencies.

Fundamental Electrical Units. An absolute determination of the ampere in terms of the mechanical units of length, mass, and time was completed, using the same modified Rayleigh type of balance last used in 1940. The results agree within 3 parts per million with those obtained last year using a radically different instrument of the Pellat type. Such absolute measurements serve as an essential precaution to detect any serious drift in the primary standards of resistance and electromotive force maintained in the Bureau's laboratories. As a further check, a repetition of absolute resistance measurements by the Wenner method was begun in January 1957.

Electron Devices. As a part of the NBS Electron Devices Data Service, a completed *Tabulation of Data on Transistors* has been made available as a mimeographed report. An NBS Circular giving a *Tabulation of Data on Receiving Tubes* is planned. Both tabulations extend the scope of the Service to give the electronics engineer a complete, active reference on these devices.

To study the rate of sublimation of materials used in electronic vacuum tubes, a sensitive vacuum microbalance with an accuracy of about 1 mg was developed for the Air Force Cambridge Research Center. It measures the metal that is lost from a surface through diffusion and sublimation. The balance will operate with a load of about 100 mg. It is expected to be useful for measuring vapor pressures of metals and alloys in the solid state.

High-Voltage Measurements. The most common cause of failure of electrical equipment is the accidental application of excessive voltage for a very short interval of time. Such high voltages can occur as a consequence of a natural lightning discharge or an electrical surge caused by an abnormal switching operation. Methods for testing the ability of electrical equipment to withstand excess voltages ordinarily make use of short-time transient voltages which closely duplicate actual operating conditions.



FOSDIC II, developed for the Weather Bureau to scan microfilmed images of punched cards containing weather data. The film scanning assembly (left) selects card images containing desired information. The information is then recorded on new cards for computer input. At right is an over-all view of FOSDIC II (p. 15).

The problem of appraising the severity of the test involves accurately measuring the crest value of the voltage surge, which may last only a few ten-millionths of a second. As two steps in the development of methods for such measurements, the Bureau derived an experimental "volt-time curve" for the standard spark gap between 12.5 cm spheres and improved a high-speed cathode-ray oscillograph to determine the variation with time of a voltage pulse lasting less than 0.01 μ sec. A special pulse generator was designed to give voltages rising to 800 volts in less than 5 billionths of a second.

Dielectric Properties of Polymers. At the beginning of the year a new Section was established to concentrate in a single group much of the research on dielectric materials and associated standardization work at frequencies below 30 kc. This group has carried out dielectric studies on well-characterized specimens of polychlorotrifluoroethylene over wide temperature and frequency ranges. The degree of crystallinity of this material can be greatly changed by varying its thermal history. Knowing how the electrical properties depend on the degree of crystallinity makes it possible to produce both highly reproducible and easily understood results for dielectric measurements.

Electronic Reliability. As the complexity of electronic equipment continues to grow, increasing attention must be given to problems of reliability and maintenance. Three programs currently under way have as their ultimate goals the easing of these problems.

The first of these programs, supported jointly by the Bureau and the Navy Bureau of Ships, is concerned with reliability predictions for transistors. Although transistors show promise of long reliable service,

trouble-free operation of transistorized equipment cannot be achieved until definite relationships are established between operating conditions and transistor performance. The Bureau is establishing realistic testing methods so that transistor parameters may be studied as the transistors are aged in various environments. Concurrently with this aging study, short-term tests that may be used to predict long-term reliability are being sought.

The second program, for the Navy Bureau of Aeronautics, seeks to improve the reliability of electronic equipment by reducing the redundancy of a wide variety of electronic circuits that provide substantially the same function. The least-common-denominator circuits being developed in the NBS Preferred Circuits Program should be instrumental in reducing the large variety of circuits currently in use. Fewer circuits will permit employment of lower-level skills in the design and maintenance of electronic equipment.

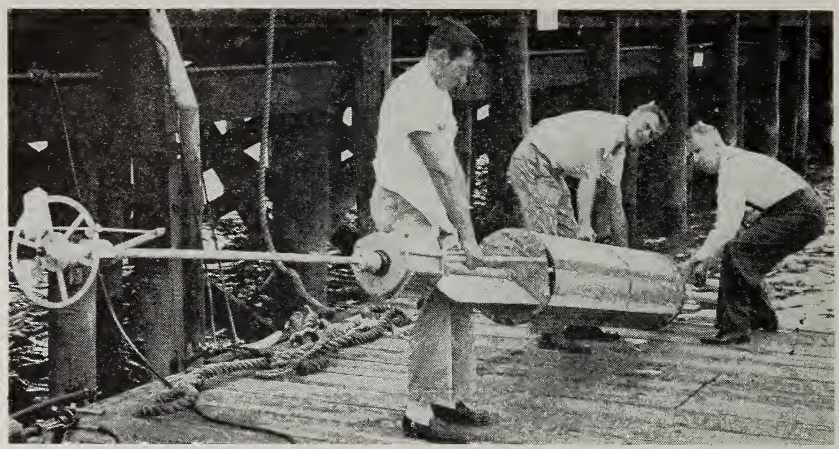
The third program, also supported by the Navy Bureau of Ships, is concerned with establishing standard expendable plug-in electronic assemblies. There is a steady growth in the number of applications where the only practical maintenance procedure calls for plug-in replacements. This program has a two-fold objective. First, criteria must be established that will dictate whether or not assemblies should be expendable in a particular application. Second, techniques must be developed for economically manufacturing reliable expendable packages.

Document-Sensing Devices. A second type of FOSDIC (Film Optical Sensing Device for Input to Computers) has been completed for the U. S. Weather Bureau. This instrumentation system selectively scans microfilmed images of punched cards containing weather information. When a desired card image is found, the system reproduces the card and continues searching for the next card of interest. The searching process is conducted at a rate of over 4,000 microfilm images per minute. A space saving of about one hundredfold in the storage of weather data will be effected by the microfilming of the present stock of approximately 300 million cards.

Transistor Wireless Microphone. A wireless microphone developed for use in the Bureau's auditorium may prove to be of general utility elsewhere. The microphone, with its transistor induction transmitter, is assembled in a small box which the speaker wears. Since there are no connecting wires, the speaker is permitted unrestricted movement in the vicinity of the lecture platform.

A loop antenna, surrounding the platform floor, delivers the induced signal to a vacuum-tube receiver that may be located remotely. The receiver supplies the signal to the public-address amplifier and loudspeaker.

Free-Floating Automatic Weather Buoy. At the request of the Department of the Navy, the Bureau modified its previously developed free-floating weather buoy for application as a hurricane-tracking device.



Free-floating weather buoy modified for use as a hurricane-tracking device. The buoy transmits information on weather conditions every 6 hours (p. 15).

Prototype models were developed which transmit by radio over an 800-mile range every 6 hours the wind direction, wind speed, barometric pressure, air temperature, water temperature, and an identification signal. It can be left unattended as long as 3 months. The prototype units have been tested with satisfactory results in the Caribbean, Gulf of Mexico, and the Arctic.

Reference Electrode for Fused Salts. A bismuth oxychloride electrode or half-cell has been found satisfactory as a reference electrode in the study of fused salts. It consists of liquid bismuth covered with a layer of zinc oxide-bismuth oxychloride and a second layer of fused zinc chloride. Its potential is 0.640 volt and its temperature coefficient is 1×10^{-4} volt per degree.

2.2. Optics and Metrology

The Bureau's work in optics and metrology deals with problems of measurement, instrumentation, and standardization in photometry, colorimetry, interferometry, optical instruments, photographic technology, and those phases of metrology that are most dependent upon optical methods. Typical activities include investigating the possible application of an atomic-beam lamp as a radiation source to be used in defining the meter, developing apparatus to produce a black body at the temperature of molten platinum, providing color standards for testing color television tubes, and developing methods for the more precise calibration of end gages to meet the demands of industry.

Standards of Illumination. The National Bureau of Standards, with six other national standardizing laboratories, participated in an intercomparison of two types of standards of candle power and two types of standards of total light output conducted by the International Bureau of Weights and Measures in Sèvres, France. The results indicate that the

units maintained by the United States standards are within a few tenths of one percent of the averages of those of the other participating laboratories, but they indicate also the need for further cooperation among the various national laboratories in order to reduce the spread in the values of the units. Toward this end, the National Bureau of Standards is setting up the primary standard for recalibration of its basic candlepower standards, and has programed recalibrations of the other types of standards of light in terms of these basic standards.

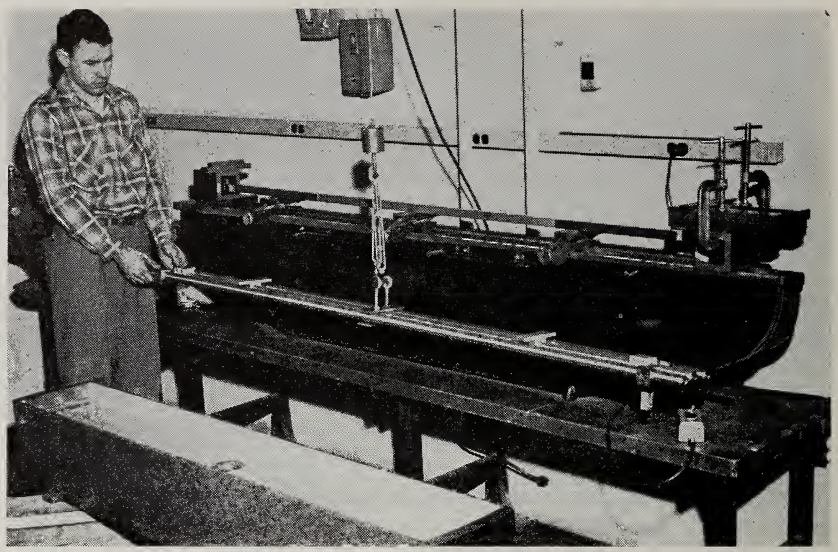
Light and Color Standards. Of importance to industries whose products are chosen largely because of their color is the normal color response of the average human eye. This applies to textiles, painted metal for automobiles, enamels, paints, plastics for refrigerators, as well as numerous other products. For several years the Bureau has collaborated with the International Commission on Illumination to determine the color responses of the average human eye under practical conditions. Work is nearing completion on a statistically determined "standard observer" for product inspection.

At the request of the Joint Electron Tube Engineering Council, the Bureau has developed light standards of red, green, and blue to test cathode-ray tubes used in color television. The standards consist of an incandescent lamp and a diffusing plate with calibrated filters.

Color standards consisting of painted panels have been devised in cooperation with the American Dental Trade Association. These standards have been distributed to suppliers of dentists' office equipment so that varied items may now be procured from different sources with assurance that colors will match.

Specification for Screw Threads. NBS Handbook H28, *Screw-Thread Standards for Federal Services*, establishes screw-thread standards for Government departments. It is also widely used throughout industry; more than 80,000 copies of the 1944 edition have been distributed. The 1957 edition, to be issued in 3 volumes, is now in preparation. Part I, covering threads for bolts, screws, and nuts (namely Unified, American, American National, and National Miniature threads), has been completed and will soon be published. Part II, now in draft form, includes standards for American Standard pipe threads, Dryseal pipe threads, gas cylinder value outlet and inlet threads, hose-coupling and fire-hose coupling threads, and welding and cutting torch hose connections. A draft of part III is expected to be completed within a year. It will include acme, stub-acme, buttress, and miscellaneous standard threads.

High-Precision Gage Blocks. Research was continued on instrumentation for more precise calibration of the gage blocks which industry uses to control the tolerances of mass-produced machine parts. The Bureau now certifies master gage blocks to an accuracy of one part in a million. However, the use of continually smaller tolerances in such fields as guided missiles and jet engines has caused manufacturers to request that the Bureau develop procedures for calibrating their master gage blocks to one part in 10 million.

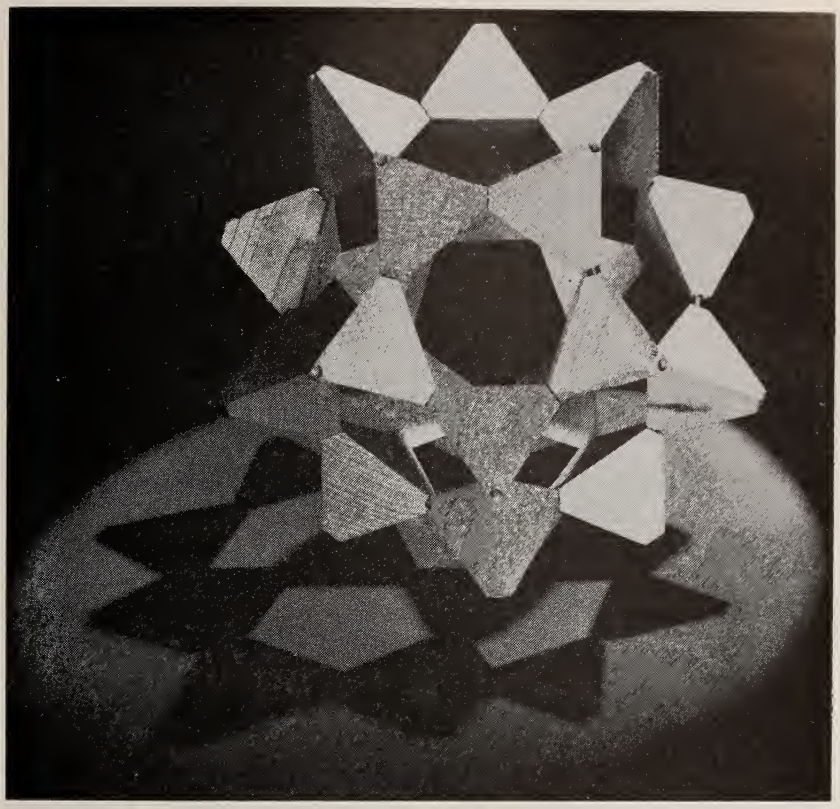


To achieve greater uniformity in measurement, the Bureau has initiated a round-robin test of the accuracy with which long lengths can be measured by different industrial laboratories. A test-casting (foreground) is shipped to representative manufacturers for measurement. Their results are checked against those obtained at the Bureau by comparison with a standard built up of end gages (shown in the background with a length-measuring machine) (p. 18).

As a part of this work, two new interferometers were developed for testing the planeness and parallelism of the measuring surfaces of gage blocks. In these interferometers the length of the gage is not a part of the optical path difference; consequently, only mechanical interference within the interferometer determines the length of the gage that can be tested. One interferometer tests gages up to 20 inches in length, but it can be readily adapted to longer gages by extending the bed of the instrument. The other interferometer tests the parallelism of gage blocks not longer than 4 inches.

The Bureau is engaged in a round-robin series of tests with approximately 20 American manufacturers to determine the accuracy with which relatively long lengths (30 to 80 in.) are measured by different representative manufacturers. Three castings have been made in a form designed to give dimensional stability, and after having been measured at the Bureau they are being shipped from manufacturer to manufacturer for measurement. Periodically, the castings are returned to the Bureau for check measurements.

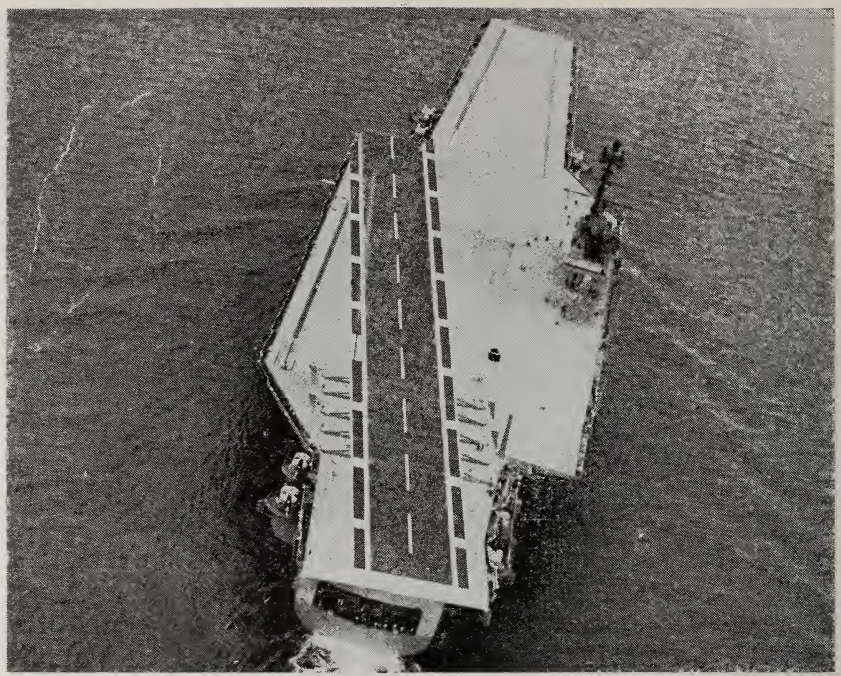
Structure of Glasses. A new concept called a vitron has been proposed for study of the glassy state. The vitron is postulated as a submicroscopic stressed cluster of definitely arranged but slightly distorted elemental groups or cages (such as pentagonal dodecahedra) which, in turn, are composed of smaller and more nearly regular stable structural units (such as silicon-oxygen tetrahedra, in the case of silica glass). As a system, these clusters tend to form at high melting temperatures and have



The vitron, a new concept developed by the Bureau for studying the structure of glass. The single-element vitron shown is constructed of 20 tetrahedra and represents 20 silicon atoms (at the tetrahedron centers) and 30 oxygen atoms (at the connecting corners) (p. 18).

some approximate noncrystal line symmetry (such as fivefold); thus, they are capable of limited but not extensive continuous growth. Such a cluster is definitely different from a crystallite, which can increase in size without limit.

The vitron concept has been applied to revise and reconcile existing theories of the structure of silicate glasses. The range of approximate order appears more extensive than formerly recognized, and the randomness is relegated to the connective material that unites the clusters. According to this view, silica glass is a continuous network within which there are wide, approximately periodic modulations in the degree of regularity of the structural arrangement, and in existing stresses and force constants. The proposed model for silica glass is consistent with known data on density, differential diffusion of gases, interatomic distances, tensile strength, unusual thermal and pressure effects on volume, and internal friction at low temperatures. Evidence to support the theory is given by analyses of property-composition curves of solubility, chemical attack, volatilization, specific volume, electrical resistance, and viscosity of binary alkali silicate glasses.



Aircraft carrier employing new markings designed by the National Bureau of Standards in cooperation with and for the Navy Bureau of Aeronautics to give improved perspective and guidance to pilots when landing. (United Press Photo) (p. 20).

Measurements of Flashing Lights. As long-range visibility is becoming increasingly important to aviation, methods for measuring the effective intensity of flashing lights have been developed both for aircraft navigation lights and for airport approach lights. The Civil Aeronautics Administration now specifies that effective intensity of flashing approach lights must be satisfactorily measured by these new methods before installation. This work was sponsored by the Navy Bureau of Aeronautics and the Wright Air Development Center.

Airplane Instrument Panel Filters. To enable a pilot to maintain his "dark" adaptation, light from the instrument panel must be red and must contain a minimum of radiant energy of shorter wavelengths. In work sponsored by the Navy Bureau of Aeronautics, the National Bureau of Standards designed a special limit filter and devised a test procedure for determining readily whether airplane instrument panel lighting meets stringent dark-adaptation requirements. During the year, 60 of these filters were supplied to industry and 8 to Government agencies.

Visual Landing Aids for Aircraft. Improved patterns have been devised for marking and lighting landing strips, both on the ground and on aircraft carriers. The markings for a carrier deck were developed in cooperation with the Navy Bureau of Aeronautics. The new patterns give the pilot a more realistic perspective of the landing area, thus enabling him to bring in his plane with greater ease.

2.3. Heat

To provide a basis for precise measurements of heat, the Bureau maintains temperature scales covering most of the range of accessible temperatures, and conducts research to extend and refine these scales. In addition, the Bureau maintains the standards for thermal measurements, such as thermal diffusivity, heat capacity, and heat of combustion, as well as standards for viscosity and for the octane and cetane number of gasoline and diesel fuels.

A broad program of supporting research and development in related fields of science is also conducted. This includes interpreting physical and chemical processes occurring at very low and very high temperatures, investigating the structure and properties of the molecules that play significant roles in such processes, and studying the behavior of gases at extremely high temperatures.

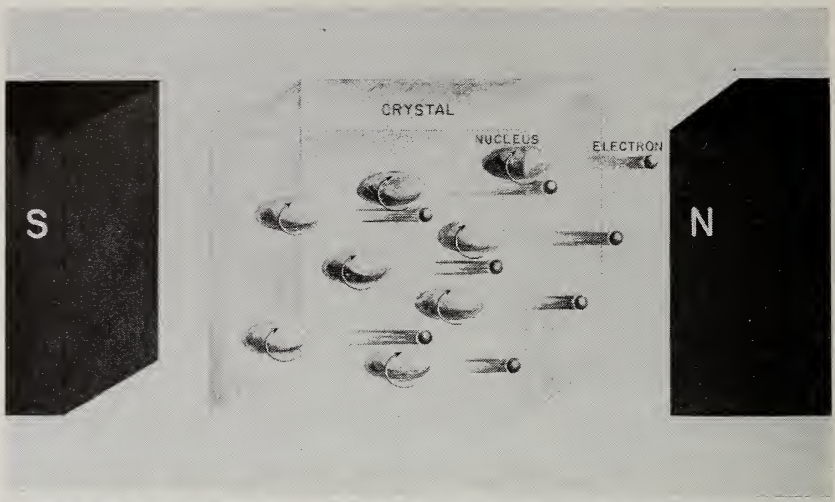
With the establishment of a new Rheology Section, the fundamental flow characteristics of solids, liquids, and gases are receiving careful and critical attention. Still other programs evaluate the performance of various fuels and investigate the mechanism of combustion processes.

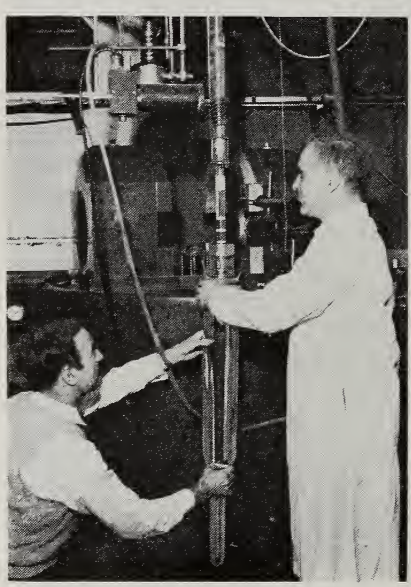
Temperature Standards. The successful use of high temperatures in research and manufacturing depends on the accuracy and precision with which these temperatures can be measured. Above 1,063° C, the freezing point of gold, the basic instrument for measurement is the disappearing-filament optical pyrometer. Instruments of this type are calibrated at the National Bureau of Standards by comparison with the Bureau's standard pyrometer. This instrument, in turn, is calibrated by observing a black body maintained at the freezing point of gold, which is one of the primary fixed points on the International Temperature Scale.

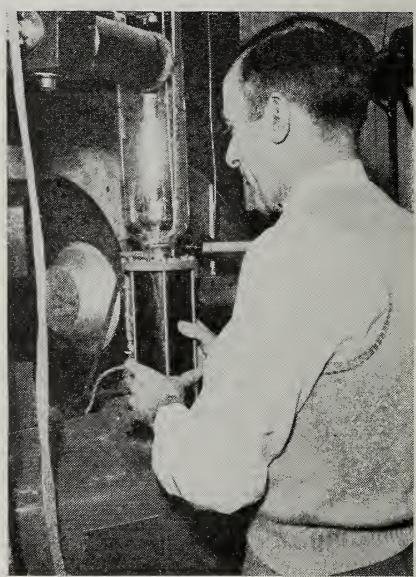
To insure that all laboratories throughout the world are operating on the same temperature scale, occasional international intercomparisons of standard instruments are made. This is accomplished in optical pyrometry through the exchange of carefully calibrated tungsten strip lamps which serve as temperature transfer instruments.

During the past year, several strip lamps were exchanged with the National Research Council in Ottawa, Canada. Two of these obtained from Canada had been calibrated also at the National Physical Laboratory, Teddington, England. The intercomparison with England and Canada, consisting of some 90 calibration points between 800° C and 2,300° C, showed a standard deviation of only 1.2 deg C. This is 3 to 6 times less than the uncertainties stated in the Bureau's certified calibrations of strip lamps and pyrometers.

An apparent discrepancy between the optical pyrometer temperature scales maintained by the Bureau and those maintained by the Physikalisch-Technische Bundesanstalt in Braunschweig, Germany has been resolved. Thus, satisfactory agreement now exists between the pyrometer temperature scales of Germany, England, Canada, and the United States.







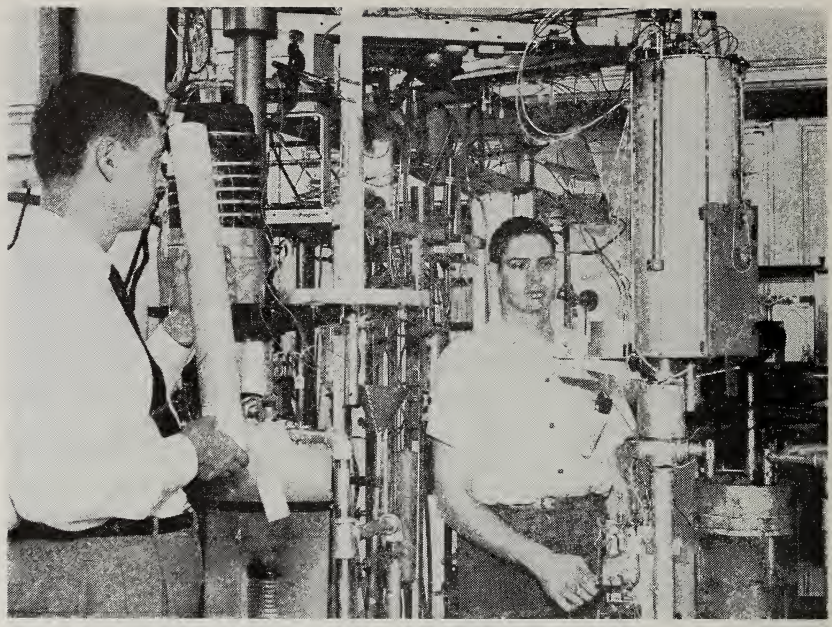
Low-temperature experiments at the Bureau demonstrated that the quantum mechanical law of conservation of parity does not hold in the beta decay of cobalt-60 nuclei. *Above:* Idealized drawing of the polarized nuclei in a magnetic field shows that the emission of electrons in beta decay favors one direction along the axis of particle spin. Since neither right- nor left-handed rotation should be favored by a greater intensity of emission if parity is conserved, this constitutes a reversal of the law of parity. *Lower left:* Apparatus used in the parity studies. An outer Dewar flask is being placed on a glass vacuum chamber containing a sample of radioactive cobalt-60. The large magnet in the background cools the sample almost to absolute zero by adiabatic demagnetization. The magnetic field of a solenoid (lower right) is then used to polarize the cobalt nuclei (p. 25).

In addition to maintaining the present temperature scale, the Bureau is responsible for improving the accuracy of this scale. A photoelectric pyrometer is being developed for this purpose. Using a photocell instead of the eye as a detector, it will eliminate personal error in making a brightness match. With this instrument, the wavelength for which a brightness match is made can be determined with greater accuracy than before, resulting in more accurate temperature determinations. Preliminary measurements show that the sensitivity is sufficient to measure temperatures at 2,000° C with a precision of 0.1 deg C. This accuracy is higher than that of the conventional optical pyrometer by a factor of 10.

High-Temperature Research. A number of theoretical investigations into the nature of high-temperature processes have been carried out under the sponsorship of the U. S. Atomic Energy Commission. Considerable progress has been made in the study of the distribution and the transfer of energy in high-temperature gases. The applicability of the equilibrium theories of chemical kinetics to fast reactions occurring in gases at high temperatures has been examined. The relaxation to equilibrium produced by collisions and by emission of radiation has been treated in detail for several types of systems. Chemical equilibrium theories were used also to analyze experimental data on the approach to vibrational equilibrium, obtained from chemical reactions and from shock tube measurements. For certain types of reactions the conventional equilibrium theories of chemical kinetics were found to lead to erroneous calculations of the reaction rates.

Thermodynamics. The majority of organic molecules found in nature are capable of hindered internal rotation. The effects of such rotation are important in determining the thermodynamic and structural properties of these molecules. Until the recent advent of microwave spectroscopy, the heights of the potential barriers to internal rotation had to be determined indirectly and with an uncertainty of at least 10 percent from a combination of vibrational and calorimetric data. Moreover, the shape of the potential barrier had to be assumed, and the details of the interactions of hindered groups neglected. Microwave spectroscopy has now made it possible in some cases to determine barrier heights with an accuracy as great as 0.5 percent, to study the details of barrier shapes, and to obtain the first direct information about the interactions of hindered groups.

The joint development of a highly sensitive microwave spectrograph and convenient methods of theoretical analysis have permitted several detailed investigations of internal rotation. Very precise analyses of propylene and some of its derivatives have been made. Furthermore, the first detailed analysis of internal rotation in the microwave spectrum of a molecule having several hindered groups has been carried out. The results have been applied to several other molecular species. In addition to providing fundamental molecular data formerly considered unattainable, these new approaches may provide the basis for a new and deeper understanding of the nature and origin of potential barriers in molecules.



New apparatus which permits the accurate measurement of heat capacity standards at high temperatures (p. 21).

In order to meet the pressing technologic and scientific demands for thermodynamic data, the properties of air and its constituents have been studied intensely in the past year. Such studies, under the partial sponsorship of the Air Force, were concerned mainly with observations made at high temperature. The equilibrium thermodynamic properties and the transport properties (viscosity, thermal conductivity, diffusion, and Prandtl number) of air at low pressure were determined. Under the sponsorship of the Atomic Energy Commission, the ideal-gas thermal functions for the atoms and ions of hydrogen, carbon, nitrogen, oxygen, and argon were established.

Significant progress has been made in methods of computing the thermodynamic properties of gases at low pressure and high temperature. The formulation of methods to represent these properties at high pressure and high temperature simultaneously is under active study. Considerable progress has also been made in the computation of the transport properties of gases at high temperatures.

Automatic equipment was applied in the control of temperatures in the low-temperature adiabatic calorimeter (range: 10° to 400° K) and in the high-temperature adiabatic calorimeter (range: room temperature to 600° C). The precision and accuracy of measurements with this type of calorimeter depend upon the quality of adiabatic temperature control. A calorimeter that ordinarily requires two operators under manual control is now handled by one operator with the automatic temperature control. The automatic equipment has been found to be more reliable

and consistent over extended intervals of time and to react more rapidly than manually-operated instruments.

Low-Temperature Physics. In December 1956 a nuclear orientation experiment in the Bureau's low temperature laboratory first demonstrated that the quantum mechanical law of parity conservation does not hold in beta decay. Carried out in collaboration with Professor C. S. Wu of Columbia University, this experiment disproved a widely accepted fundamental concept of nuclear physics, thus clearing the way for a reconsideration of current theories.

In the summer of 1956, T. D. Lee of Columbia University and C. N. Yang of the Institute for Advanced Study had proposed a number of experiments that might determine whether or not parity is always conserved.[2] One of these experiments involved measuring the directional intensity of beta radiation from oriented cobalt-60 nuclei. If parity is conserved in such an interaction, then the intensity of the beta emission should be the same in either direction along the axis of spin. At the suggestion of Professor Wu, arrangements were made to carry out this experiment at the Bureau.

Polarization of the nuclei was achieved by cooling a sample of cobalt-60 to within 0.01 deg (Celsius) of absolute zero, and subjecting it to a magnetic field. When a magnetic field is applied at this temperature, most of the cobalt-60 nuclei are alined so that their spin axes are parallel to the field.

It was found that the emission of beta particles is greater in the direction opposite to that of the nuclear spin. Thus, a spinning cobalt-60 nucleus has a beta emission distribution that is not the same as that of its mirror image. This result unequivocally demonstrated that parity is not conserved in the emission of beta particles by cobalt-60.

Within a very short time, the results obtained at the Bureau were confirmed by other investigators, and a great deal of activity was stimulated in the field of subatomic particles. Although it is too early to predict in detail the consequences of this discovery, it is clear that much detailed information about fundamental particles and their interactions will be obtained. Such information may well modify many of the present theories of fundamental particles and their interactions.

Combustion. Investigations of the various modes of oxidation of propane, the simplest hydrocarbon which exhibits combustion reactions typical of higher hydrocarbons used as fuels, have recently been carried out under the sponsorship of the Air Research and Development Command. Isotopic tracer studies of the slow, or cool flame, oxidation of propane-2-C^{13} have yielded information on the origin of many of the products. Findings generally confirm current theories of the cool flame mechanism.

Application of similar methods to the investigation of the hot flame, however, have revealed unexpected features of this reaction. For ex-

[2] Drs. Lee and Yang received the 1957 Nobel Prize in Physics for their theoretical work in disproving parity conservation.

ample, the lower hydrocarbon products of rich explosion flames, such as ethylene and acetylene, do not arise directly from a two-carbon fragment of the carbon chain of the fuel, but appear to be synthesized in the flame from simpler radicals or molecules by reactions as yet unidentified. Similar reactions take place in the thermal decomposition of propane at temperatures greater than 1,200° K. Thus there is an opportunity to study them in a high temperature system simpler than a flame.

The use of shock-wave heating techniques is being investigated for possible application to the study of flame initiation, thermal decomposition, and flame reactions of mixtures outside ordinary inflammability limits.

2.4. Atomic and Radiation Physics

The reliance of modern industrial technology and military defense upon advances in atomic and nuclear physics is producing a constant demand for additional and improved standards, for new methods of measurement, and for more extensive and precise data. The Bureau's program in atomic and radiation physics is designed to meet the most urgent of these needs through basic and applied research on particles such as atoms, nuclei, neutrons, and electrons; properties of radiation, particularly gamma and X-rays and ultraviolet and infrared light; and the interactions between radiation and particles. Emphasis is on phenomena involved in interactions between radiations, or between free elementary particles, and matter in bulk (solids, liquids, or gases). Work is also going forward in the closely related area of solid state physics, where the results are contributing to better understanding of crystalline substances and give promise of information useful in the field of electronics.

The results of such studies, both at the Bureau and elsewhere, are evaluated and compiled for publication in handbooks and circulars, which make the data readily available in the most useful forms for engineers, scientists, the medical profession, and others. The understanding of basic processes revealed by these studies is also of great value to the Bureau in devising suitable standards of measurement and in providing essential calibration services for new instruments and materials.

Radiation Protection. The Bureau has long played an active role in research on radiation protection problems. In this work it has collaborated closely with the International Commissions on Radiological Units and Measurements and on Radiological Protection (ICRU and ICRP, respectively). This it has done both in research projects carried out in its own laboratories and through the work of staff members serving on the Commissions and their subcommittees. Problems of radiation units and measurement have received strong emphasis along with problems of radiation protection, and the work of the ICRU has continued to expand under its Secretariat at the National Bureau of Standards.

As a result of a request to the International Commissions from the United Nations Scientific Committee on the Effects of Atomic Radiation,

Spectroscopic research yielded detailed information about electronic configurations in atoms. Studies of the actinium spectra (insert), for example, revealed that the element introduces a series similar to the rare earths (p. 27).

an intensive study was undertaken to examine the feasibility of a national or international system for maintaining records of the dose received by individuals in the course of medical use of ionizing radiations. At joint meetings, held at New York in November 1956 and at Geneva in April 1957, Bureau staff members participated in a study of the problems of the effect of medical exposure on the radiation tolerance of the population. A number of systems for the collection and recording of information on radiation dose were examined, including programs that might have been undertaken by various government agencies in this country. It was concluded that establishment of dose records of the general public is not feasible at the present time because of the inability to secure adequate input data. The results of last year's deliberations have appeared as NBS Handbook 62, which is the 1957 report of the ICRU.

Spectroscopic Research. After 5 years of intensive effort, the third volume of *Atomic Energy Levels*, NBS Circular 467, was completed. Derived from 124 spectra, it contains all available information on energy levels, quantum numbers, magnetic splitting factors, and electron configurations of 32 chemical elements (42 Mo to 57 La, and 72 Hf to 89 Ac). Most of the new information presented on technetium, ruthenium, iodine, hafnium, tantalum, rhenium, and actinium resulted from research at the Bureau. Also, the results for three successive spectra of actinium have been published. They show that actinium introduces, in the 7th period,

another group of 14 rare earths in which f-type electrons will be more or less firmly incorporated into the outer structure of the heavier elements thorium, protactinium, uranium, neptunium, plutonium, etc.

High-Altitude Observatory. A unique high-altitude observatory was established on the slope of the Hawaiian volcano, Mauna Loa, for joint use by NBS and the U. S. Weather Bureau. Located at a height of 11,134 feet in the tropics, where the upper atmosphere is very clear and usually of low moisture content, the new observatory offers special advantages for many types of astronomical and upper-air studies. It will make possible continuous observation of atmospheric phenomena with manned instruments in place of the unmanned meteorological balloons that have been used for the most part in high-altitude work.

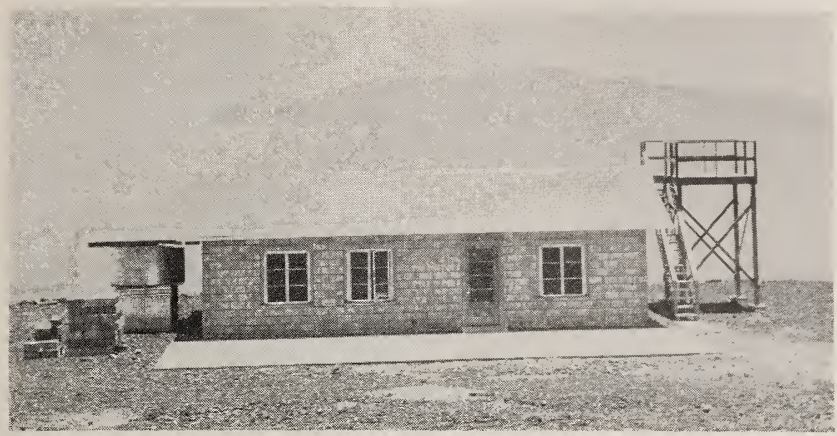
One study, supported by the National Geographic Society, was completed on the moisture and oxygen content of the planet Mars. The data were obtained by comparison of spectroscopic observations of sunlight reflected from Mars and the Moon to the Earth. Another investigation, still in progress, includes observation and analysis of the spectral distribution of energy in the radiation from the sun. Supported by the Air Research and Development Command, this work will provide information on the effect of solar energy in connection with high-altitude equipment, satellites, and space flights.

Solid State Physics. One of the principal concerns of the recently developed field of solid state physics is with the properties of semiconducting materials, the best known application of which is the transistor. In research supported partly by the Department of Defense, work continued on the physical properties of semiconducting intermetallic compounds, with emphasis on indium antimonide (InSb). Further light was thrown on its energy-band structure and a basis was laid for possible practical applications.

The resistance of n-type InSb as a function of magnetic field strength at helium temperatures has shown an oscillatory behavior. The magnetoresistive effect in this material, even at magnetic fields of a few thousand gauss, appeared considerably larger than in any other solid and could be enhanced by special geometries of the specimens. This high magnetoresistance as well as the Hall effect can be utilized in constructing such devices as magnetometers, gyrators, and low-frequency amplifiers.

A study was made of InSb, which had been deliberately contaminated with copper, at wavelengths beyond the absorption edge up to 35 microns. Extrinsic absorption peaks and photoconductivity were observed in this range of the spectrum. Another property investigated during the year is the change of resistance under stress. Resistance measurements on both n- and p-type InSb gave important information on the energy band structure of this compound.

Since its discovery 11 years ago, nuclear magnetic resonance has been shown to be one of the most fruitful techniques for the study of solids



High-altitude observatory established on the slope of the Hawaiian volcano, Mauna Loa, at a height of 11,134 feet. This unique observatory will be used jointly by NBS, the Weather Bureau, and others for astronomical and upper-air studies (p. 28).

This type of experiment has now been initiated, and both continuous wave and pulse methods are available. The technique will be applied to the investigation of imperfections in semiconducting crystals.

Electron Physics Tables. Designed to facilitate the computations of scientists and engineers engaged in research with electron beams, design work, or applications, a set of Electron Physics Tables were completed during the past year and published as NBS Circular 571. They replace the out-of-print, partially obsolete, and less extensive tables issued in 1941. Calculated with the help of the Bureau's automatic computer, SEAC, 8 quantities are tabulated with over 3,000 entries for each. Values are given with 8-figure accuracy and cover a range of electron energies from 0.206 to 3.353×10^{12} electron volts. The electron quantities tabulated are the potential difference, in absolute volts, required to accelerate an electron from rest to a specific kinetic energy; the effective relativistic potential difference; the product of magnetic field times the radius of curvature of the electron path in the field; the de Broglie wavelength; the momentum in units of m_0c; the kinetic energy in units of the rest energy; the total energy in units of rest energy; and the ratio of the electron velocity to the velocity of light.

Scattering of Low-energy Electrons. In a continuing program jointly supported by the Office of Naval Research, the Atomic Energy Commission, and the Bureau, research was directed toward a better understanding of the processes involved in low-energy electron scattering. An instrument was completed that can extend the measurements to greater precision and range of angles than previously possible. With this instrument, new information concerning the variation of energy loss with angle and the effect of crystalline orientation has been obtained. The studies have also been extended, for the first time using modern instruments, to the losses occurring in vapors.

Neutron Penetration in Water. The first of a series of experiments, supported by the U. S. Atomic Energy Commission, on the penetration of neutrons in water has been completed. These experiments use simple geometries and are designed to check theoretical calculations. The calculations may then be used in the design of nuclear reactors and shielding for protection of personnel near neutron sources such as particle accelerators, nuclear reactors, and radioactive neutron sources. To obtain nearly monoenergetic neutrons for these experiments, nuclear reactions made by bombarding a target with a deuteron beam from a Van de Graaff accelerator are used. The target is located in the middle of a large tank of water and detectors may be moved about throughout most of the tank.

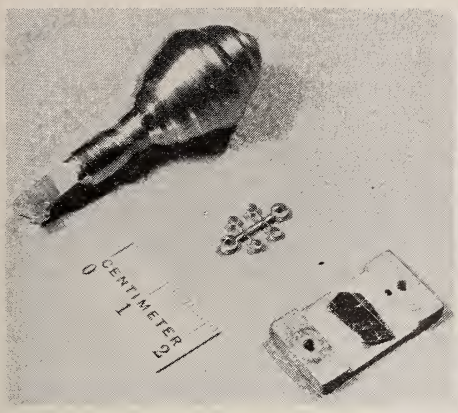
In the first experiment, 14.1 million-volt neutrons were used. The spatial distributions of fast neutrons, indium-resonance neutrons, and thermal neutrons were measured. The results of this experiment are in agreement with theoretical calculations. The "age", or ⅙ of the mean square of the crow-flight distance that the source-neutrons travel while being slowed down to 1.44-volt energy, was found to be 150 ± 6 square centimeters.

A second experiment on the "age" of neutrons is now in progress using neutrons that range in energy from about 2 to 3.5 million volts. This measurement is of particular interest because the energy of these neutrons is near the average energy of fission neutrons. Thus the information is important for nuclear reactor calculations.

Penetration of Gamma Radiation. Extensive calculations of gamma-ray and electron penetration were made in work supported by the Atomic Energy Commission, the Office of Naval Research, and the Federal Civil Defense Agency. The results will ultimately be of value in design of bomb shelters and reactor shielding, theory of radiation monitoring instruments, and radiation biological damage studies.

Extensive tabulations have been made of basic input data, i. e., the information required for interpreting and predicting radiation effects. Two important compilations of this type were published—one on gamma-ray attenuation coefficients, the other on electron stopping powers and ranges.

Ionization Chamber for Calibrations. The gold-leaf electroscope has been used for many years as the means of calibrating small radium and cobalt-60 sources by intercomparing the gamma rays of the unknown source with those from radium standards. In making a calibration, several measurements of the transit time of the gold leaf with the unknown and the standard are required. To reduce measurement time as well as radiation exposure of personnel, a reentrant-type ionization chamber was designed in which the sources are introduced into the chamber along its axis. The volume of the chamber was chosen so that direct measurements of ionization current could be made with a considerable saving in time. A chamber was constructed on the basis of a preliminary study



Left: **Some examples of semiconducting intermetallic specimens studied at the Bureau include indium-antimony samples (top and center), and magnesium-tin (bottom). Research on intermetallic compounds has not only led to improved transistors and photodetectors but has also suggested the use of semiconductors in power sources and refrigerating units (p. 28).**
Right: **To investigate the behavior of gamma rays near the boundary between two media, a scintillation detector is inserted into a pipe that passes through a steel-wool mass containing radioactive cobalt (p. 30).**

of the various parameters, and a detailed study of the characteristics of the chamber is being carried out. Attention is now being given to means of compensating for differences in the length and wall material of the unknown and standard sources, improvements in electrode and air volume geometry, and to possible extension of the system to semi-automatic operation.

Ionization Measurements. The output of most X- and gamma-ray sources with energies of 3 million volts or less is measured in roentgens. For X-rays of up to 500 kilovolts, the primary standard is the free-air ionization chamber. For million-volt rays, however, such a chamber must be made so large that only a few laboratories have considered its construction. Instead, a cavity-type ionization chamber is used. Its sensitivity is determined either by its response to a known quantity of radioactive material or from certain factors whose magnitude is somewhat in question. In order to provide information for such calibrations, the Bureau has determined the roentgen-per-hour radiation at 1 meter for 1 milligram of radium. In addition, the output of a small source of cobalt-60 and of cesium-137 has been measured with a large pressurized free-air chamber and with a cavity chamber. The final results agreed with each other to about 1 percent. Thus, for the first time, there is an overlap in the two methods of measurement. The cavity chamber experiment also indicated which of the currently published factors is correct.

Low-Energy X-Rays. Extensive use of X-rays has underlined the need for more quantitative information about the process of X-ray production. Experimental investigations are therefore being carried on with the support of the Atomic Energy Commission to measure important features

of X-rays produced in thin targets with monoenergetic electron beams of energies between 50 and 1,000 kilovolts. Results obtained thus far are helping to establish a consistent quantitative picture of the X-ray production process.

Data have been obtained for the X-ray angular and energy distributions as a function of electron energy and target material. Also, measurements have been made of the total energy radiated by monoenergetic electrons in passing through a thin target. A specially designed polarimeter has been constructed and used in studies of the polarization properties of the X-rays produced in thin targets. The experimental results appear to show that improvements are required in free available theoretical approximations which are currently in use.

High-Energy Accelerator Research. Significant progress was made during the last year on three projects aimed toward a better understanding of the basic interaction of high-energy X-rays with matter. In the first of these projects, supported by the Air Research and Development Command, it was found possible to use the scattering of 15.12 million-volt X-rays to study in detail the shape of the X-ray spectrum from a high-energy electron accelerator. Measurements were made to within 30 kilovolts of the high-energy tip of the spectrum. Knowledge of the shape of this spectrum will be of considerable use in interpreting data on nuclear energy levels obtained with betatrons and synchrotrons.

The other two projects, supported by the Atomic Energy Commission, have provided information about the structure of the nucleus. In the first, it was shown that the study of the photoproduction of π° mesons from carbon leads to information regarding the distribution of nuclear matter within the carbon nucleus. In the remaining study it was shown that a correlation exists between the photoneutron yield from a given nucleus and the deformation of the nuclear surface. This has opened up an entirely new approach to the study of intrinsic nuclear quadrupole moments.

Photographic Films for X-ray Measurements. Photographic film for the measurement of radiation has been used extensively in atomic weapons tests, so that previous studies were carried out at high-radiation intensities in the reversal region of the characteristic curve. More comprehensive investigations of the photographic reversal effects have now been undertaken; and a study of reversal as a function of photon energy as well as of exposure rate is in progress.

A calculation of the energy delivered to the emulsion showed that within the energy range and exposure rates so far investigated, the reversal effect depends upon the rate of energy absorption by the emulsion, rather than on photon energy or on exposure rate. Particularly revealing were the results of a study using mixed exposures, i. e., two successive exposures of different rates of energy absorption achieved either by employing different photon energies or different exposure rates. So far, no difference in the microscopic appearance of the developed grains

could be demonstrated for exposures involving different rates of energy absorption, although microscopic studies of grains in the ascending and descending (reversal) branches of the characteristic curves obtained under fixed conditions tend to show a difference in the number of developed grains and grain size in the two branches. The work on mixed exposures was extended to include successive exposures to visible light and X-rays and to visible light and infrared light. An evaluation of the results of these experiments is now being carried out.

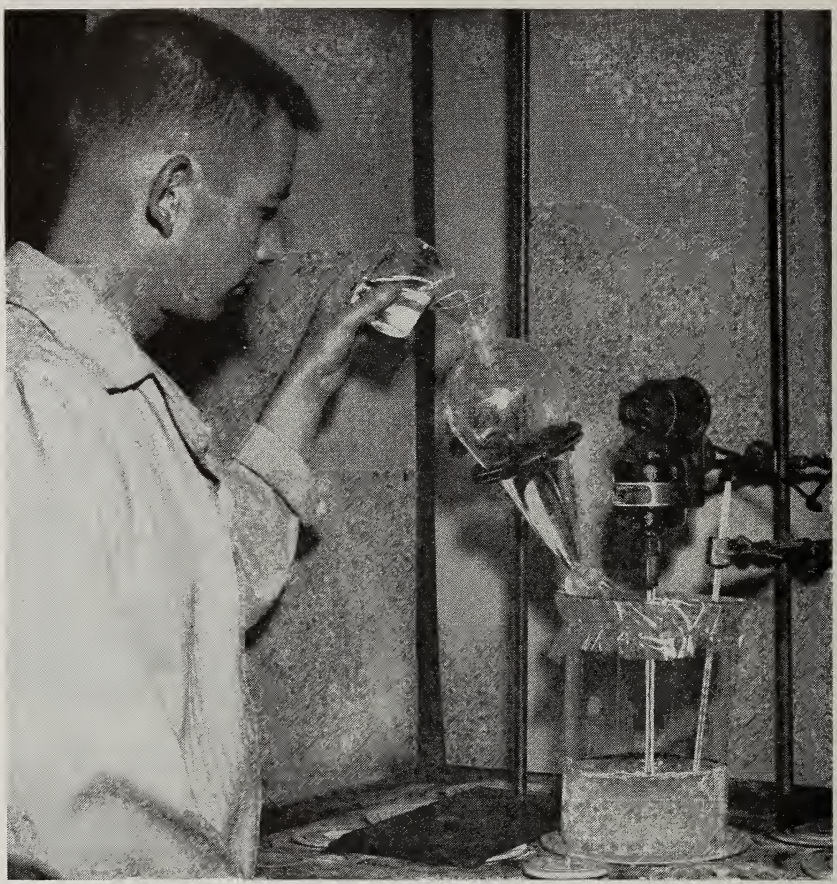
2.5. Chemistry

The Bureau carries on a wide range of fundamental and applied research in physical, analytical, organic, and inorganic chemistry. Special laboratories are devoted to organic protective coatings, detergents and adsorbents, carbohydrates, electrodeposition, gas chemistry, acid-base indicators and *p*H standards, pure substances, spectrochemistry, and thermochemistry. Representative activities during the year included investigations of analytical procedures, development of methods for separating and purifying substances, electrophoresis studies, research on light scattering by colloidal particles, growth of crystals, synthesis of carbohydrates labeled with radioactive carbon, applications of absorption and emission spectrometry, chromatography studies, collection and critical tabulation of scientific data, and the preparation and certification of standard samples.

Inorganic and Analytical Chemistry. At the request of the Diamond Ordnance Fuze Laboratories, an entirely new analytical procedure was developed for the separation of titanium, iron, zirconium, and aluminum from one another. This method, combined with a previous process which is effective in the separation of silicon, barium, strontium, calcium, and magnesium, provides a means for determining and controlling the composition of barium titanate ceramic dielectrics vital to the country's national defense. Several halides of titanium were prepared in a state of high purity for determination of their fundamental physical properties in a program sponsored by the Office of Naval Research. Terbium oxide in which no other rare-earth element could be detected spectrochemically was prepared for use in determining the spectral structure of terbium, one of the rare-earth elements that have been separated from one another by ion exchange.

Several methods were devised for the separation and determination of minute quantities of a substance. One such procedure was for detecting small amounts of arsenic, phosphorus, and silicon in ammonium molybdate, while another was for finding trace quantities of iodide polarographically. Measurements designed to yield the second dissociation constant of calcium hydroxide were also completed.

The methods of assaying purity of nearly pure compounds were given considerable emphasis and advances were made in methods of purification. The more striking advances dealt with processes of crystallization,



Barium titanate is used extensively in electronic devices because of its desirable dielectric and piezoelectric properties. To aid in relating these properties to composition, a method was developed for preparing the material in very high purity (p. 33).

mechanisms by which impurities are retained in growing crystals, and the more perfect separation of crystalline matter from melt or mother-liquor. The growth of crystals from solution seems always to be accompanied by the retention of some impurities. Aqueous solutions of ammonium phosphate contaminated with chromium ion have yielded valuable information regarding the causes of this retention. It was observed, for example, that when the crystals grow perpendicular to one group of faces the chromium is almost totally excluded from the crystals, whereas growth upon another group of faces permits almost half of the contamination to be retained by the crystal. Obviously, if the crystals can be grown so that growth is restricted in the direction where retention occurs, great improvement in total purity is possible.

Spectrometric analysis of high-purity gases was investigated to devise a rapid, accurate method for the determination of impurities. A process was developed in which a glow discharge in the glowing gas is excited by

a high-frequency electric field. The light is observed with an automatic scanning photoelectric spectrometer. A minimal effect of contamination and maximum control of pressure and flow rate of the gas are provided by the gas handling system. With this technique, the impurities, nitrogen, water vapor, and hydrogen can be measured in concentrations as low as 1 part per million and the time required is only 6 seconds per element. Because of its high speed, the procedure is particularly well adapted for monitoring the composition of a continuously flowing gas.

In connection with the assay of NBS acidimetric standard benzoic acid and acid potassium phthalate, a highly accurate method was developed or the coulometric titration of acids and bases. This technique involved measurement of the time required for accurately measured constant current to neutralize an acid or base. A precision of 1 part in 10,000 can be obtained.

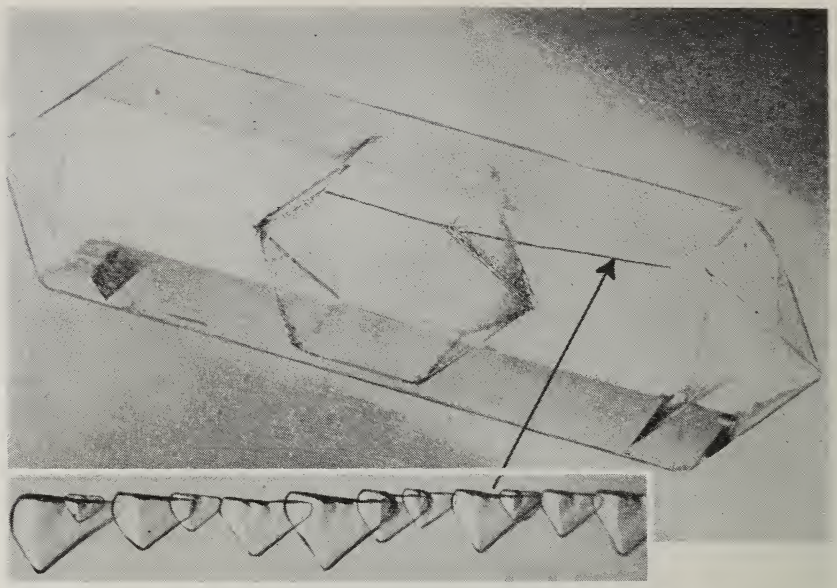
Physical and Electrochemistry. The electrodeposition of metals from organic solutions has been a relatively unexplored field although its possibilities appear very promising. In this area, specific accomplishments of potential value for the Atomic Energy Commission and the Department of Defense were the deposition of beryllium, magnesium, titanium-aluminum alloys, zirconium-aluminum alloys, and the improvement of the aluminum plating process developed in 1952.

To settle the question of the acidity or alkalinity of stoichiometrically neutral solutions of reagent chemicals, the *p*H values were determined for 38 reagent chemicals, each in 5-percent concentration.

A gage to measure the thickness of chromium plating in machine-gun bores was developed and constructed for the Army's Springfield Armory. In this gage, the basic circuit of the "Dermitron", which was devised at the Bureau in 1953, was used to meet the requirements of the Army.

In connection with the saline water project of the Department of the Interior, for the production of fresh water from salt water, permselective membranes were successfully prepared by the simultaneous cross linking and quaternization of polyvinyl pyridine with alpha, omega-dichloro hydrocarbons. This technique expands the possibilities of controlling the structure of the membranes and is of importance in theoretical studies of their behavior.

A study of the dielectric properties of compressed gases was continued, with major emphasis on symmetric top and near symmetric top molecules. In these molecules, a part of the dipolar loss is of the nonresonant (Debye) type. Study of the relaxation times governing this Debye-type loss, at pressures where only bimolecular collisions are important, can provide much information regarding molecular interactions. During the past year, considerable progress has been made in obtaining new data and in correlating the relaxation times with pertinent molecular parameters, such as dipole moment and moments of inertia. These measurements also provide a new, accurate, and very sensitive method of determining electric dipole moments. For example, perchloryl fluoride (ClO_3F) was



Advances were made in purification by crystal growth. A single crystal of ammonium phosphate shows that mother liquor (dark line) is entrapped on the faces of the seed crystal. The photomicrograph insert shows that this liquid, which retains impurities, is contained in crystallike pockets. Restricting the direction of growth can improve the total purity (p. 33).

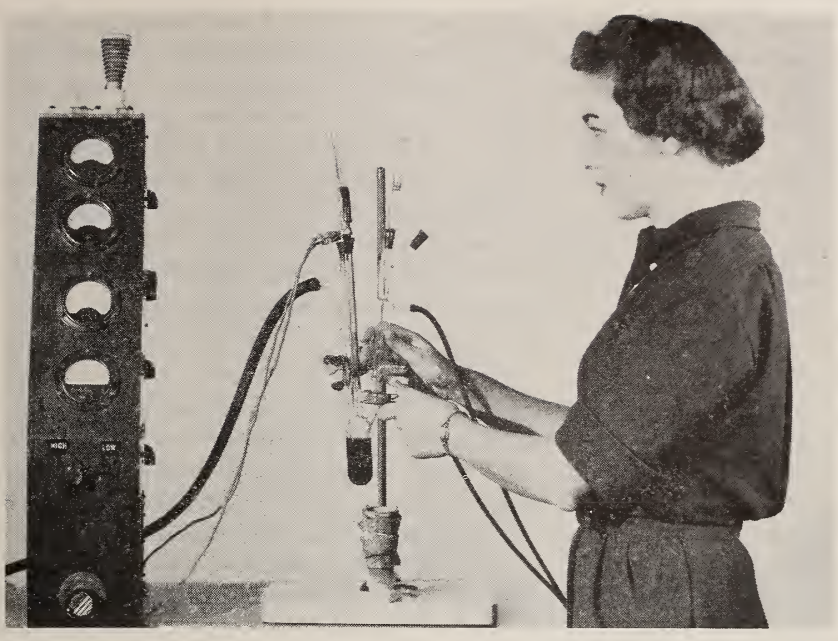
found to have a dipole moment of only $0.023 \pm 0.003 \times 10^{-18}$ esu. This value is about one-fourth that of carbon monoxide, which had the smallest value reported until now. The new method thus extends the range of dipole moment measurements beyond the limits of the more conventional methods such as the microwave Stark effect.

Heats of formation of titanium tetrachloride, tetrabromide, and tetraiodide were determined. The data, collected for the Office of Naval Research, are of importance in the metallurgy of titanium.

The Raman spectrum of triethylborane was measured to obtain frequency shifts and polarization data. Tentative assignments were made for most of the observed bands by comparison with the spectra of trimethylborane and ethane. This work is a contribution to studies of the structures of a series of important boron-carbon compounds. The project is supported by the Navy Bureau of Aeronautics.

Organic Chemistry. The relative strengths of 40 aromatic carboxylic acids in benzene were determined. This comprehensive investigation provides improved understanding of the influence of the solvent on the behavior of important organic acids and is correlated with electrochemical and spectrochemical data in the literature.

In work sponsored by the Atomic Energy Commission, methods were developed for the synthesis of radioactive carbohydrates labeled with carbon-14 and tritium. These materials are used as tracers in biology



The Bureau has electrodeposited several of the refractory and light metals. Because the deposition potentials of these metals are so far above hydrogen, they must be deposited from organic rather than aqueous solutions (p. 35).

and medicine. Until the materials become commercially available, the Bureau will prepare and distribute the compounds at cost. New products synthesized included L-ascorbic acid-6-C^{14}, L-fucose-1-C^{14}, L-idurone-6-C^{14}, L-rhamnose-1-C^{14}, and 1,2-isopropylidene-D-idose-6-C^{14}.

A study of the influence of steric factors on the rate and course of chemical reactions was continued. Earlier studies of the mutation and oxidation of aldoses had indicated a relationship between the conformation, or shape of the pyranose ring, and the rate of reaction. The alpha and beta positions were presumed to differ with respect to the plane of the ring, thus accounting for the striking difference found experimentally in the reactivity of the alpha and beta sugars. The importance of ring formation has since been recognized and techniques developed for its study. Under the sponsorship of the Office of Naval Research, the infrared absorption of a large group of carbohydrate derivatives was measured and a system devised for classifying the compounds by correlating infrared absorption with structure. Results showed that certain sugars exist in more than one conformation, which can be assigned with more certainty to fused ring structures than to single rings. For this reason, the spectra of a group of isopropylidene compounds having fused ring structures are now being investigated.

Spectrophotometric measurements on substituted derivatives of 4,4′-diaminodiphenylsulfone were made to obtain values of molar absorbance and related data.

Air Pollution. A method has been devised for interpreting mass spectra of samples of smog condensed at the temperature of liquid nitrogen. Such samples are too complex for interpretation by the usual methods. Analysis of samples from many sources now under study for the U. S. Bureau of Mines leads to the conclusion that most smogs contain relatively high concentrations of "traffic gas". The infrared spectrum of the free methyl peroxy radical, which is typical of those thought to be present during reactions in smoggy atmospheres, was obtained, and a rapid, simple method was developed for the determination of acetylene in air in the range of 10 parts per million to 10 parts per billion.

2.6. Mechanics

Basic to the Bureau's program in mechanics is the development, improvement, and maintenance of standards, and the development and evaluation of techniques for the measurement of a large variety of mechanical quantities. These include volume capacity, weights and other forces, static pressures, the flow of liquids and gases, vibration amplitudes, and the speed, attenuation, and intensity level of sound. To provide fixed points for comparison and otherwise to supplement these basic activities, precise determinations are made of physical constants and properties of materials, such as density, viscosity, and sound-transmission characteristics. In addition, fundamental research is performed in the mechanics of solids and in fluid dynamics.

Measurement of Sound and Vibration. The measurement of very high sound intensities in the vicinity of jet aircraft has become important in recent years. This requires microphones calibrated at high intensities, where distortions occur because of the relatively large forces impressed on the instrument. A null method for calibration has been devised, which effectively removes distortions caused by the microphone, and makes possible the measurement of certain types of intense sounds without the removal of energy from the sound field. This method is particularly applicable to condenser microphones.

The same type of microphone lends itself to use as a standard source of vibration when voltage is applied to it. A method for using it to calibrate vibration gages over the frequency range from 10 to 30,000 cycles per second was completed.

Perplexing differences exist between measurements, made in various laboratories, of sound absorption coefficients for acoustical materials. These differences are attributed to the fact that the randomness of the sound field, which is necessary for accurate measurement, is partially destroyed by the walls of the chamber in which measurements are necessarily made. Also, the absorption of sound is influenced to an unexpected degree by the size of the sample. Methods have been devised for correcting the influence of the walls on absorption measurements, and a rational scheme has been worked out for estimating the effect of small sample size on sound absorption.

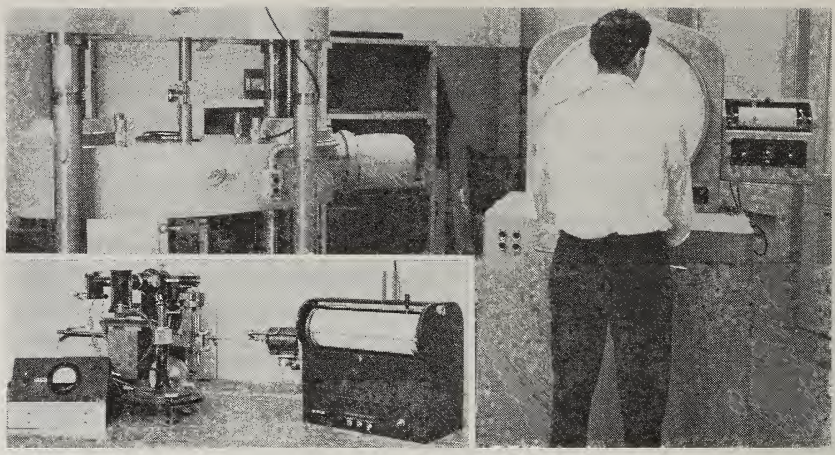
High-frequency sound is useful for measuring the physical properties of matter. An accurate method was developed under the sponsorship of the U. S. Navy for measuring the speed of sound in water, in which the time of flight of a pulse of sound is measured. Speeds have been measured with an error much less than 0.01 percent. The method will be applied to the calibration of velocimeters to be used in sea water, where the speed of sound must be known for sonar used by the Navy.

Hygrometry. A continuing demand exists for improved instrumentation for measuring the humidity of gases for industrial and scientific purposes. During the past year, effort has been directed toward setting up a standard hygrometer that would be suitable for calibrating other instruments for precise work in research and industry. The design of a gravimetric hygrometer for use as a standard was completed and construction initiated. An airborne version of the microwave hygrometer is being developed for use with high-altitude, high-speed military aircraft for the Navy Bureau of Aeronautics.

Pressure Measurement. Under sponsorship of the Ballistic Research Laboratories, Army Ordnance Corps, construction was undertaken of an improved pressure-measuring device for dynamic calibration at high pressures. Work continued on a new pressure standard for calibration of high-altitude instruments under the sponsorship of the Air Force. Advances were made on the use of manganin pressure gages for high static pressures, under the sponsorship of Army Ordnance Corps, Watertown Arsenal.

Mixing in Bodies of Water. In land-enclosed bodies of water, the wind produces a surface drift which causes a reverse current at lower depths. Where properties vary with depth, as in lower lying saline layers or regions with vertical temperature gradients, the circulation created by the reverse current causes mixing of these properties. This is of considerable importance, particularly in engineering projects for the desalination of isolated bays. The mixing by wind action and resulting circulation is being studied on a laboratory scale under the sponsorship of the Office of Naval Research. In this investigation the advance of a saline front into fresh water has been charted, and laws of mixing have been determined as functions of wind velocity and duration.

Fluid Slip at Nonwettable Surfaces. Experiments have established that no slip occurs at the surface between a solid and a fluid flowing over it. Flow therefore consists of shearing motions within the fluid itself. It has never been proved, however, that slip must be universally absent, and it has often been supposed that slip is a distinct possibility at a surface which is not wetted by the fluid in which it is immersed. If slip should occur, or could be made to occur, reduction in surface friction might be expected. This possibility has been investigated under the sponsorship of the Office of Naval Research, in connection with hydrophobic materials, which are not wetted by water. Teflon is one such material which has been studied in considerable detail by measuring the resistance to flow in Teflon tubes and the resistance experienced by oscillating disks. In no case could any evidence of slip be detected.



During the past year, the Bureau conducted a study on the accuracy of stress-strain recorders, such as the one shown in the process of plotting a stress-strain diagram. Calibrations were performed by the apparatus in insert and results were made available to industry. The interferometric comparator (left) is equipped with a photoelectric counter (far left) (p. 40).

The conclusion was reached that the nonwetting property alone does not involve the kind of contact between fluid and solid that permits slip. This does not preclude the possibility that some other surface-to-fluid property might permit slip. So far, no such property is known.

Stress-Strain Recorders. Laboratories engaged in testing the strength of materials such as steel, concrete, fabrics, rubber, and plastics make extensive use of autographic recorders to plot graphs of stress and strain. Although these devices have been in use for many years, there has been a lack of information about their accuracy. During the past year the results of performance studies of representative instruments, conducted under the sponsorship of the Atomic Energy Commission and the Department of Defense, were made available to industry. The tests included calibrations of the stress and strain coordinates, as well as the measurement of other important characteristics such as the expansion of the graph paper in humid weather. It was found that the instruments generally met the requirements for accuracy set up by government and industry.

Dynamic Properties of Materials. The emphasis placed on loading considerations in design has led to an increase in the number of structures built to resist dynamic as well as static loads. Investigations of the behavior of structures subjected to rapidly applied loads are being conducted by more and more laboratories. These activities have increased the need for more exact knowledge of the dynamic properties of structural materials since the physical constants determined under static load conditions do not adequately describe the behavior of most structural materials when subjected to rapidly applied loads.

To comply with this demand, a "sling shot" machine was constructed which fires a weight axially at one end of a long bar of structural material

with sufficient velocity to send a plastic strain pulse along the bar. Several techniques for recording these pulses at three stations simultaneously have been employed in an attempt to obtain consistent values for the stress-strain relations under very high rates of loading.

Density of Tungsten Wire. To meet industrial demands, the effect of drawing on the density of very fine tungsten wire was observed and a precise determination of the density of the drawn wire was made. From the weight of a known length, the cross-sectional area and diameter may now be computed. However, obtaining an air-free sample of sufficient magnitude for reliable hydrostatic weighing presents a problem. In an attempt to obtain such a sample, a definite reaction (corrosion) of distilled water on tungsten was observed. By modifying the procedure, the effects of this reaction were virtually eliminated.

Jet Engine Controls. A continuing program in jet engine controls, sponsored by the Wright Air Development Center, U. S. Air Force, is aimed at improving immersion-type temperature sensing devices for jet engines. Because of the high temperatures and speeds, the accuracy, rate of response, and durability of these devices must be improved if safe and successful operation of aircraft gas turbines and jet engines is to be maintained. Thus far, greater accuracy in observations of the response rate of sensing devices has been attained and several fast-responding instruments have been examined. A satisfactory rate of response has been obtained, but the durability of the faster devices is inadequate.

Since several thermocouples normally are connected in parallel to obtain an average reading of exhaust gas temperatures, a knowledge of the contribution of each thermocouple to the reading on the indicating instrument is necessary. If, because of lead resistances, contributions of the several thermocouples have different weights, some means must be devised to weight them equally. A comprehensive analysis was made of several parallel thermocouple systems, weighting factors were determined, and methods of compensation were presented. An outgrowth of this task was construction of an electrical analog which can be used to simulate any harness system having up to 12 thermocouples. Thus weighting factors can be determined and compensation made.

Aircraft Fuel Accessories. Optimum performance of a gas-turbine engine in flight requires precise adjustment and calibration of the fuel metering and control components prior to installation on the aircraft. Conventional methods of adjustment utilize static test procedures, but experience is demonstrating that these are not always sufficient for accurate predictions of the dynamic performance of controls during flight. Thus, a program to develop instrumentation, equipment, and procedures for the dynamic evaluation of gas-turbine fuel metering and control components is being sponsored by the Navy Bureau of Aeronautics. A closed-loop fuel control test stand, containing an analog computer to simulate existing jet engines, is now being installed for this purpose.

Also, evaluation studies have been undertaken on different makes and sizes of electronic, turbine-type flowmeters to determine their suitability as flow transducers.

Gas Turbine Radiation. Gas temperatures in turbine-type engines soon will exceed the operating range of currently used immersion-type temperature-sensing devices. This necessitates the development of a flight instrument that does not have the inherent disadvantages of the sensing devices now in use.

Particular interest has been shown in the development of an instrument that will sense gas temperature from the radiating characteristics of the hot products of combustion. The Wright Air Development Center has requested the Bureau to investigate the emission and absorption of hydrocarbon combustion products and to furnish the results to the industrial contractor developing the essential components of such a flight-type radiation pyrometer.

Observations have been made on streams of exhaust gas at temperatures from 1,000° to 3,500° F. Special emphasis was placed on the wavelength region between 4 and 5 μ, where many vibrational transitions of carbon dioxide occur. Considerable effort was given to the theoretical and experimental study of intensity gradients and their effects on the accuracy of sensing devices. These investigations have established the feasibility of an airborne pyrometer.

2.7. Organic and Fibrous Materials

The Bureau conducts research on natural and synthetic polymeric materials, including rubber, textiles, paper, leather, and plastics. These materials are composed of very long, chainlike molecules formed by the process of polymerization. Many of their useful properties depend upon the size, shape, distribution, and flexibility of their molecules. To advance fundamental knowledge of these industrially important materials and thus aid in their efficient utilization, the Bureau investigates the mechanisms involved in forming polymers, their constitution and molecular structure, and methods of measuring their properties. The data obtained are of value not only in developing new polymeric materials having specific properties, but also in devising techniques for evaluating material already in use.

Basic research during the year provided information on such topics as transition temperatures of elastomers, processes involved in the degradation of cellulose by light, effects of high-energy radiation on polymers, and mechanisms of failure in plastics under tensile loading. Methods were developed for testing the smoothness of paper and the sewability of sewing thread. In research conducted in cooperation with the American Dental Association and the Federal dental services, significant contributions were made to knowledge of tooth structure and the properties of dental materials.

Glass Transition Temperatures of Copolymers. Rubbers and other elastomers become rigid and unfitted for normal use below a characteristic

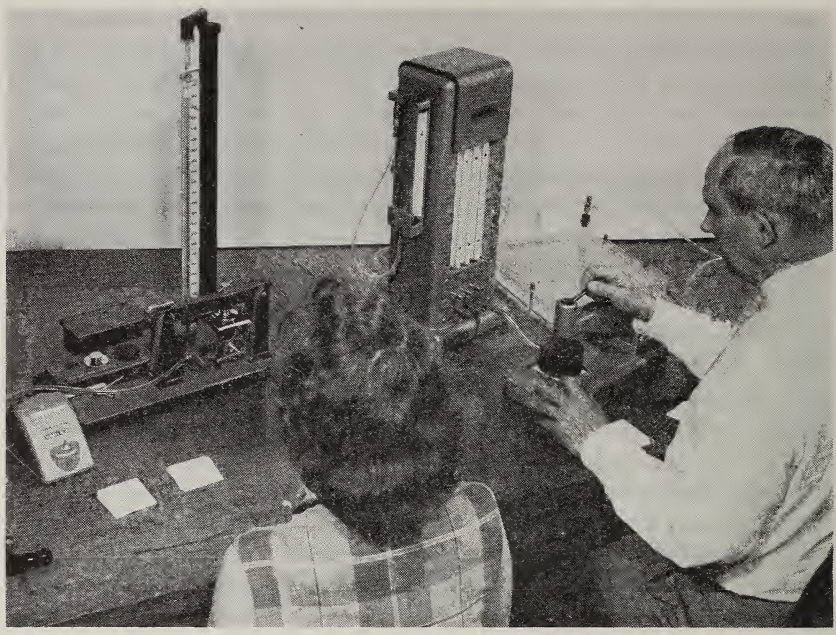
temperature called the glass transition temperature. This temperature can be conveniently studied by measuring the volume or density of the material over a wide range of temperature, and then noting a break in the curve that represents the volume as a function of temperature. Studies are under way to determine how the glass temperature of a given polymeric material will vary with systematic changes in the molecule, such as variation in molecular size, change in chemical composition, or introduction of branching or side groups onto the main chain of the molecule.

If the elastomer is a copolymer, the glass temperature can be related to the glass temperatures of the components. Recent work has demonstrated the form of this relationship by an examination of all available data. It was found that the glass temperature can be represented as the weighted mean of the glass temperatures of the constituents. The observed weighting factors, however, do not correspond to those predicted by theories assuming ideal mixing in copolymer systems. Methods of determining the weighting factors have been developed and utilized in a number of two-component systems. Detailed studies have been made of the commercially-important butadienestyrene copolymers, formerly the government-produced GR–S and presently designated as SBR rubbers, and a system of fluorine-containing copolymers.

Degradation of Cellulose by Ultraviolet Light. The degradation of cellulose by light is important in the deterioration of textiles and paper. Hence, a knowledge of the primary processes involved has both practical application and fundamental scientific value. In a recent investigation, sheets of dried, purified cotton cellulose made at NBS were irradiated at 40° C with ultraviolet light of 2537 A wavelength. The gases evolved were approximately 90-percent hydrogen and 10-percent carbon monoxide plus carbon dioxide. The evolution of hydrogen followed a parabolic rate law, indicating inhibition by a product. The irradiated cellulose was analyzed for changes in degree of polymerization, aldehyde group content, and carboxyl group content. A close stoichiometrical parallel existed between carboxyl formed and the calculated number of chain fractures, indicating that these reactions may be related. It appears that the main reaction at this wavelength is the photolysis of the alcohol groups in the cellulose to produce carbonyl groups, with the liberation of hydrogen gas.

Effects of High-Energy Radiation. Atomic radiation often induces undesirable degradation reactions in polymeric materials. Therefore, new materials must be developed that will be able to withstand this radiation. On the other hand, the availability of ionizing radiation offers opportunities for producing new materials with improved physical properties and a greater practical value.

To solve the problems connected with high-energy radiation, a basic knowledge is needed of the mechanisms of the processes and reactions involved. Recent experimental work on the effects of irradiating polymers



Comparing a rapid new instrument (right) for measuring the smoothness of paper with an older-type instrument (left). Both instruments use an air-leak system. Although the new instrument is less sensitive at extreme values, its rapidity makes it more useful (p. 45).

indicates that the mechanism of these reactions involves free-radical intermediates. Assuming homogeneous kinetics and the presence of these free-radical intermediates, a theory has been developed which explains the basic features of the effects of high-energy radiation on polymers. The knowledge of these mechanisms suggests new fields of experimental attack on the problem, the results of which should aid in developing new techniques and methods for improving polymeric materials by atomic radiation.

Fracture of Plastics. The fracture characteristics of plastics yield valuable clues to the mechanism of failure, and thus have importance in design and application considerations as well as in fundamental investigations of structure and dynamics. In recent studies of fracture behavior, tensile specimens of cast polymethyl methacrylate of different molecular weights were broken by static loading, and the fracture surfaces compared. The fracture appearance was fairly constant for a given molecular weight, but with changes in molecular weight a continuous development was observed of certain features and a retrogression of others. The series of fracture patterns caused by varying the molecular weight was similar in appearance to a series, reported in the literature which was developed by varying the rate of loading. Thus, molecular weight is an important parameter, which must be considered along with rate of loading in fundamental studies of the fracture behavior of polymers.

Smoothness of Printing Paper. The type of printing and the end use of the printed paper determine the optimum value for smoothness of paper. For some applications the smoothness should be a maximum, while in others it should be within specified limits.

A new instrument for measuring the smoothness of printing papers has been compared with an older type of instrument by use of the Mandel-Stiehler sensitivity criterion. This criterion is especially useful where there is no absolute standard of comparison and no simple proportional relationship between the results of the two methods.

Both instruments use an air-leak system. The older one requires measuring the time for a fixed volume of air under specific pressure to pass between the paper and an optical flat; the new instrument requires observation of the bob in a precision flowmeter. For all but very smooth papers, a close but complicated relationship was found between the values given by the two methods. The new instrument was more sensitive in the middle range of smoothness values; the other was more sensitive at the extremes. However, the new instrument requires about one-fifth as much time for a reading, so that its lesser sensitivity at the extremes can be compensated for by measuring a greater number of specimens.

Sewability of Cotton Thread. Cotton thread for high-speed industrial sewing must have such an impact-absorbing capacity that the sewing can be accomplished at speeds up to 5,000 stitches per minute. In work sponsored by the Army Quartermaster Research and Development Command, the Bureau evaluated the mechanical properties and impact-absorbing capacity of cotton threads which varied systematically in fiber quality, spinning twist of yarn, ply twist of thread, and amount of finish. Both dyed and undyed threads were studied. A critical analysis of the results showed that the kind of cotton, the ply twist, and dyeing affected the thread properties greatly. The spinning twist and the amount of finish had only a minor effect. Quantitative relationships were found which point to a number of criteria for laboratory evaluation of the sewability of cotton thread.

Fluorescence of Human Enamel and Dentin. The degree of calcification in tooth tissue contributes greatly to the physical properties of the tooth. During the year, studies of the fluorescence of human enamel and dentin under ultraviolet radiation, made jointly with the American Dental Association, showed that the intensity of fluorescence may be used to measure the degree of tooth calcification. The periodic high and low calcification of the developing tooth produces alternate bright and dark bands in the fluorescence photographs of enamel and dentin. Poor calcification at any period during the formation or growth of the tooth appears as a highly fluorescent zone in the portion of the tooth structure formed during that period. Thus, fluorphotographs of the tooth sections indicate the growth patterns of the teeth in the same way that the rings of a tree indicate its growth pattern.

Improved Material for Treating Teeth. Zinc oxide-eugenol mixtures have a wide variety of applications as tooth-treating materials in dentistry. However, the presently available commercial zinc oxide-eugenol mixtures harden rapidly only in the presence of accelerators. The products have low strength and can not be used with plastic filling materials as they interfere in the hardening of the resin.

Chemical analysis of the reaction products showed that a zinc eugenolate with a ring (chelated) structure is formed during the hardening process. When other compounds that are capable of forming chelate rings with metal oxides were substituted, products that harden quickly at room temperature without the use of accelerators were obtained. These materials had much higher strength than the commercial materials now available. Mixtures containing zinc oxide-ethoxybenzoic acid and eugenol seem especially promising for making improved dental impression pastes or temporary filling materials.

Structural Changes in Rubber During Vulcanization. Information on the structure of vulcanized rubber is essential to the interpretation of results obtained through vulcanization and oxidation, and to an understanding of the physical properties of rubber. In recent work, infrared absorption was used to study the structures resulting from different methods of vulcanization. Sulfur vulcanizates showed the presence of a shifted double bond previously noted; a newly discovered band indicated the presence of conjugated double bonds. Some accelerators were found to increase the rate of double-bond shift and reduce the number of conjugated double bonds. Neither the double-bond shift nor conjugation is observed in several types of vulcanization which do not involve the use of elemental sulfur, but other structural changes occur in these vulcanizates. Apparently the double-bond shift and conjugation are phenomena primarily related to the chemical reactions between rubber and elemental sulfur. The other systems studied evidently involve different mechanisms of vulcanization. This work implies that there may be a relationship between susceptibility to oxidation and the amount of conjugation in the vulcanizates. Both quantities are highest for sulfur vulcanizates, intermediate for sulfur-accelerator systems, and lowest for sulfurless vulcanizates.

Oil-Extended Rubber. Knowledge of the composition of oils used in oil-extended synthetic rubbers is helpful in specifying types of oil and in understanding the properties of the oil-rubber master batches. In work sponsored by the National Science Foundation, infrared analysis was applied to two series of oil fractions separated by basically different methods. Fractions of a number of different oils or oil distillates were studied. The spectra were compared as to the method of separation, and, in some cases, as to the physical and chemical properties of the fractions. Marked similarities were noted between certain of the fractions separated by the two methods. However, a variability of structural types from one oil to another was indicated, especially in the more polar fractions. It ap-

pears that this variability, particularly in the polar groups and other structures leading to active hydrogens, could account for the observed variability in the aging properties of master batches containing different oils or oil fractions.

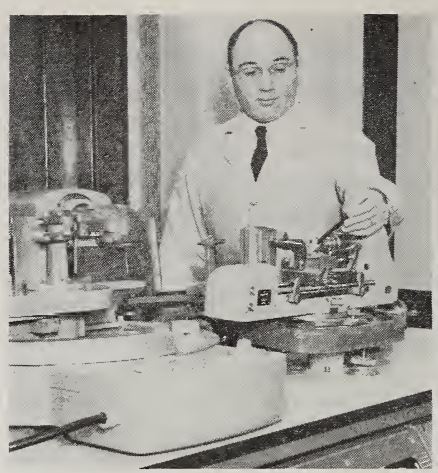
Influence of Temperature on Chrome Tanning. One of the most important methods of converting hide into leather is to apply a basic chromium sulfate solution to the hide. Tanners have known for many years that temperature plays an important role in this reaction. Both the rate of tanning and the amount of chromium sulfate which combines with the collagen increase with an increase in temperature. The exact function of temperature, however, has not been understood, and rigid temperature controls are not used in tanneries.

Results of recent work showed that the amount of chrome combined at 50° C was 3 to 4 times greater than that combined at 0° C. An analysis of the data indicated that the sulfate ($SO_4^{=}$) combined in the leather consisted of two components: one which was constant at all temperatures, and one which varied in the same ratio with the amount of chrome (Cr_2O_3) at all temperatures. The first component had combined with free basic groups in the leather protein, and the second was combined in the chrome tanning complex. The formation of the chrome tanning complex depends on hydrolysis which increases with increase in temperature. The influence of temperature, therefore, may be explained from the increase in the rate of hydrolysis, which produces more active chrome complexes to combine with the collagen.

Heats of Wetting. Organic and fibrous materials, when placed in water, evolve heat. The source of the heat is assumed to be the reaction of the water with certain active groups present in the materials. Measurement of this heat of wetting in a calorimeter provides a quick, simple procedure for obtaining an over-all estimate of the water adsorptive properties High water adsorptive capacity contributes to the comfort-giving qualities of natural and synthetic fibers and plastic materials used in the manufacture of footwear and clothing.

The heats of wetting were determined of a series of organic and fibrous materials, including proteins, chemically modified proteins, textile materials, plastics, and leathers. Of the materials examined, the leather-making protein, collagen, was shown to have the highest heat of wetting. Good correlation was obtained between the experimentally determined heats of wetting and the polar active groups of the proteins. Conversion of collagen to leather by either chrome or vegetable tanning reduces the heat of wetting, but the value still remains considerably higher than the values for the more water-adsorptive synthetic or plastic materials. Of the synthetic fibers and plastics, vicara, which is prepared from the protein zein, and polyvinyl alcohol showed the highest heats of wetting.

Mildew-Proofing of Leathers. The fungicide used by the Army Quartermaster Corps for protecting leather is 4-nitrophenol. This compound is not entirely satisfactory from the standpoint of color, water solubility, and toxicity to human skin when present in excessive amounts.



Left: **Data obtained in X-ray studies of the hydroxyapatite crystal are useful to scientists studying inorganic structure and mineralized body tissues (p. 50).**

Right: **Developing a treatment to prevent mildew on leather. Specimens are kept in an oven at 30° C to simulate an environment conducive to fungicide growth (p. 47).**

Recent research, sponsored by the Army Quartermaster Research and Development Command, disclosed that bis(4-nitrophenyl) carbonate and bis(2-chloro-4-nitrophenyl) carbonate may offer some important advantages over 4-nitrophenol, while being just about as effective. These compounds are colorless, comparatively water-insoluble, and reportedly less toxic to human skin. Under mildew-growing conditions they are hydrolyzed to the corresponding free phenols. They, therefore, offer the unique possibility of incorporating into the leather a nontoxic material which becomes fungitoxic only under the specific conditions requiring a fungicide. In view of the difficulty of finding an effective leather fungicide that is not toxic to human skin, this behavior is important. Analytical methods have been developed for the bis compounds based on the decomposition to free phenols and these methods are being used in further studies of stability characteristics of the compounds.

Sedimentation Equilibrium of Flexible Chain Molecules. Molecular weight, molecular weight distribution, and molecular configuration greatly influence the physical properties of high polymeric materials such as plastics, rubber, paper, and textiles. One of the best means of obtaining information on these molecular properties is by appropriate physical measurements on dilute solutions of the materials. The equilibrium centrifuge, developed in Sweden by Svedberg, has long been used to determine weight-average molecular weights of polydisperse polymer systems. Work at the Bureau has shown both theoretically and experimentally that to obtain reliable weight-average molecular weights the solvent and temperature employed must be suitable; in particular, "ideal

solutions" are required and it was demonstrated that they can be obtained in the equilibrium ultracentrifuge. As a consequence of these studies, methods can now be developed to measure absolute molecular weights.

Effects of High Rates of Straining. The increasing use of plastics to withstand impact and high accelerations requires knowledge of their behavior under these conditions. Plastic items that encounter impact include tools, safety helmets, body armor, shuttles, and disposable plastic parachutes.

Under the sponsorship of the Army Quartermaster Research and Development Command, a method of impacting textile fibers and yarns was adapted to impact plastics films. Each impact event was recorded by a high-speed motion picture camera. Data obtained from the photographic film are used to compute the stress-strain curve. The energy to rupture and the maximum strain at rates of straining of 400,000 to 800,000 percent per minute were determined with 3-mil-thick polyester plastic film and compared with data obtained at conventional testing speeds. The results may be used to evaluate plastic film for making disposable parachutes. Data obtained with other plastics may be used to gain insight on the behavior of these materials under impact-loading conditions.

Effects of Molding Pressure on Reinforced Plastics. Plastic laminates reinforced with glass fiber have many structural applications; for example, aircraft component parts and radomes in which high strength-to-weight ratios and nonmetallic properties are essential. Relatively high molding pressures were considered necessary where maximum strength was required. This resulted in high fabrication costs.

A recent study of the effects of molding pressure, sponsored by the Air Force, Wright Air Development Center, revealed that, when glass-resin ratios of the laminates are held constant by using a closed mold, changes in molding pressure from 10 to 500 lb/in.^{2} have no significant effect on the strength properties of the laminates. In open-mold laminating techniques, where excess resin is allowed to flow out of the mold, changes in molding pressure from 1 to 100 lb/in.^{2} cause significant variations in strength properties. These variations, however, can be related to the variations in the glass-resin ratios of the laminates.

Surface Erosion of Plastics. Plastics in structural applications are commonly reinforced with organic or inorganic fibrous materials to improve impact and flexural strength. When reinforced plastics are used in structures that must be periodically decontaminated or otherwise subjected to cyclic wetting and drying, surface erosion often results.

Microscopic investigation of a large number of reinforced plastics was undertaken, under the sponsorship of the Army Quartermaster Research and Development Command to determine the mechanisms involved in this erosion, and to develop materials with improved erosion resistance. It was found that surface deterioration in plastics with inorganic fillers, such as glass fiber or asbestos, is caused largely by failures in the bond between the resin and the fibers, although crazing sometimes plays a significant role. Local stress concentrations leading to chipping and

spalling in the superficial layers result. Organic fillers apparently absorb moisture through the resin and swell. When close to the surface, this swelling causes considerable damage to the integrity of the material.

For most materials, the only available solution appears to be the application of an overlay to protect the fibers from contact with moisture. This can be accomplished through the use of organic materials such as polyester film, by laminating external metal sheets to the plastic structure, or by the application of gel coats. Several other possible devices to improve resistance to erosion, however, remain to be explored.

Gallium Alloys. The investigation of the use of gallium as a component of dental-filling materials was continued with the support of the American Dental Association and the Federal dental services. It was found that an alloy, made by mixing a liquid consisting of an approximate eutectic composition of gallium and tin with a powder of copper and tin, had good mechanical properties from a dental restorative standpoint. This gallium alloy had approximately the same setting expansion as dental amalgam but greater compressive strength, hardness, and modulus of elasticity. However, as the alloy corroded excessively it was not satisfactory for use as a dental restorative material.

A second alloy composition, consisting only of gallium and tin, has much better corrosion resistance. With the exception of a high setting expansion, this material has mechanical properties similar to the gallium-copper-tin alloys. The development of nickel-base alloy powders to reduce the setting expansion could result in a new satisfactory filling material.

Color Standards for Dental Materials. Color is an essential property of filling materials for front teeth. The present system of color designation for such materials has been empirically developed by individual manufacturers. Lack of standardization causes confusion among the users and difficulty in teaching clinical application. Also, difficulties have arisen in Government procurement.

In research on silicate-cement filling materials, a standard means was recently devised for defining the shades in a scientific numerical system. The Gardner automatic color difference meter was used, after modification for specimen size, to measure the tristimulus values (X, Y, and Z) for a wide range of shades of silicates which are made to match natural teeth. This research, sponsored by the Federal dental services and the Bureau, has as its long-range objective to define numerically the color of all dental materials where esthetics is involved.

Crystal Chemistry of Mineralized Tissue. The mineral prototype of bone and tooth hard substance is called hydroxyapatite [$Ca_{10}(PO_4)_6(OH_2)$]. By the use of X-ray diffraction techniques, an analysis of the three-dimensional arrangement of the atoms in this structure has been completed. The parameters for the structure were determined by an electronic computer. A clear definition was derived of the positions in space of the calcium, phosphorus, and oxygen atoms, and also of the hydroxyl groups which comprise the hydroxyapatite crystal. The improved data will be

useful to physical chemists, physicists, mineralogists, and other scientists studying inorganic structures. In addition, the exact knowledge of atomic placement in apatite will serve as a guide for further investigation of the mineralized tissues of the body. This work was sponsored by the American Dental Association.

In cooperative work with the National Institute for Dental Research on the crystal chemistry of bone and tooth mineral, the acid solubility of enamel in experimental animals was reduced by pretreatment with calcium acetate solution. Similar results were obtained with synthetic apatites deficient in calcium ions. These findings are theoretically significant because of the indication that hard tissue is similar to defect apatites prepared in the Bureau's dental laboratory. Clinically, they could lead to a treatment to reduce the solubility of teeth, and thereby decrease caries incidence.

2.8. Metallurgy

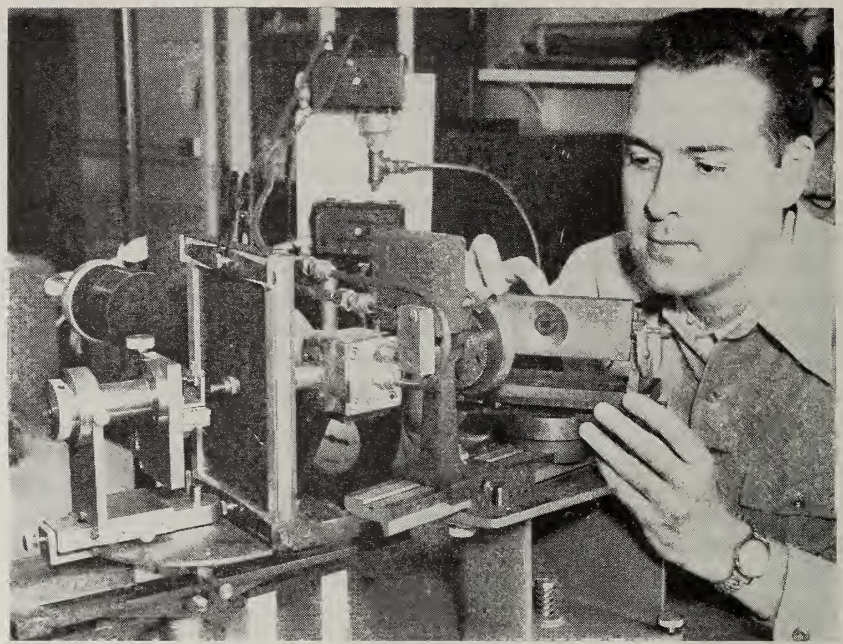
The Bureau's work in metallurgy is concerned with the physical, chemical, mechanical, and thermal properties of metals and alloys and with their behavior under both normal and abnormal conditions. The objective of the program has always been to increase both theoretical and practical knowledge of metals in order to provide the improved materials constantly demanded by science and industry. A new metal physics laboratory has been instituted to augment the theoretical work carried on in the Metallurgy Division. It will be noted that much of the program described in the following paragraphs is slanted toward properties and behavior of metals at high temperatures. This emphasis is a result of the higher temperatures developed in high-speed aircraft and other modern devices.

Equilibrium Diagrams. To understand and predict the behavior and best utilization of alloys, it is advantageous to have detailed equilibrium diagrams that show their melting ranges, structural changes occurring at various temperatures, intermetallic compounds, and solubility-temperature relationships.

In research sponsored by the Atomic Energy Commission on the alloys of uranium with the platinum metals (platinum, palladium, rhodium, ruthenium, osmium, and iridium), the equilibrium diagram of the platinum-uranium system was brought to completion. Much of the exploratory work on the other platinum metals has been done, and progress has been made on the somewhat complicated uranium-palladium system.

Studies of the controversial magnesium-zinc alloy system, sponsored by the Air Force Wright Air Development Center, are nearly completed, and work on the quaternary system, iron-chromium-molybdenum-nickel, is being continued.

Deformation of Metals. For the past several years the Bureau has been investigating the rheological behavior, at subzero and elevated temperatures, of high-purity nickel and copper, and alloys of the nickel-copper system. Particular attention has been given to the creep mechanism of



Studying structural stresses in metals by X-ray diffraction. This technique permits precise determination of the interatomic distances in crystals. Even very small stresses change this spacing and can therefore be determined by diffraction methods (p. 52).

these polycrystalline metals at different temperatures, and to evaluating the experimental data in terms of existing and proposed theories and equations. None of the existing equations is entirely suited for defining the extension-time relationship in each of the three stages of creep.

An evaluation was made of the stress-rupture properties at 1,350°, 1,500°, and 1,600° F of a die-cast cobalt base alloy for the Navy Bureau of Ships. The results showed that the stress rupture properties of the die-cast material were somewhat inferior to those reported in the literature for precision cast specimens. This inferiority was especially noticeable in initially aged specimens, and at temperatures of 1,500° or 1,600° F.

Microscopic Stresses in Metals. The usual commercially important metals are extremely inhomogeneous on a microscopic scale. This is because they are polycrystalline aggregates and may be made up of two or more phases. As the crystals are generally anisotropic and the different phases may have widely different coefficients of linear thermal expansion, it has been shown theoretically that the inhomogeneous contraction on cooling from the liquid state should set up microscopic stresses in the metal. Actual measurement of such stresses is difficult because of the extremely short distance over which they operate. Recently, such measurements have been made by means of X-ray diffraction techniques, which permit highly precise determination of the interatomic distances in crystals. As the application of a stress causes a regular change in the

spacing of the atoms, and as the X-ray diffraction technique "sorts out" the separate phases, it is possible to measure these microscopic stresses if they affect one phase differently from another. Using very careful surface preparation procedures to avoid introducing extraneous stresses, measurements were made on a carbon steel and a two-phase brass. In each case the experimentally determined stresses agreed reasonably well with those calculated from the known thermal expansion coefficients of the separate phases. The results add experimental weight to knowledge that was previously largely theoretical, and they show the impossibility of obtaining a completely stress-free condition in metals that contain more than one phase differing in coefficient of linear thermal expansion.

Corrosion. In studies partially supported by the Corrosion Research Council, it was found that light may have a marked influence on the corrosion process. A copper single crystal, immersed in air-saturated water and illuminated on one side by white light from a 3,200° K lamp, showed remarkably different rates of corrosion on the illuminated and dark sides. The film on the lighted side was only one-fourth as thick as that on the dark side after 3 hours' illumination. Further, when similar light was allowed to impinge on part of a crystal immersed in water and already containing a rather thick oxide film (1000 to 2000 A), the oxide on the illuminated portion appeared to dissolve after a period of 2 or 3 hours and to become considerably thinner than on the part of the crystal kept dark.

Studies also showed that the corrosion of single crystals of metals is influenced by the crystal structure; and that both the formation of oxide films in water and the deposition of thin layers of metal upon similar metal surfaces bear definite relationships to the underlying crystal structures. Basic studies on the influence of crystallographic orientation demonstrated that the corrosion of single crystals of high-purity aluminum in strongly acid or alkaline media is an orderly process, the rate of attack depending on the orientation of the corroding surface.

A method using polarization curves was developed for determining the instantaneous rate of corrosion on ferrous metal surfaces exposed to corrosive media. This method provides a means for studying the rate of corrosion while it is taking place, and may be of value in the preliminary screening of materials for service in specific corrodants.

Materials for Ultraprecise Gage Blocks. The Bureau now calibrates industrial master gage blocks, which are used as standards for controlling the accuracy of mass-produced machine parts, to an accuracy of 1 part in 1 million. This means that inch-long blocks are certified to the nearest millionth of an inch. However, as mechanized industry has become increasingly complex, the dimensional tolerances that can be permitted in machine parts is continually decreasing. Makers of machine tools have therefore requested the Bureau to undertake research that will make it possible to calibrate master gage blocks to a precision of 1 part in 10 million.

An important phase of this program is the selection, preparation, treatment, and evaluation of materials for gage blocks of the required

To meet the need for increasingly smaller tolerances in the aircraft and other industries, the Bureau is conducting research directed toward the calibration of gage blocks to one 10-millionth of an inch (p. 53). Representatives of industry are shown observing progress made in increasing the dimensional stability of gage blocks (p. 53). They are inspecting apparatus which applies extremely hard nitrided cases to steels.

precision. These materials must have sufficient hardness to resist wear, and a high degree of dimensional stability. It is highly desirable that the gages have approximately the same coefficient of expansion as the material to be gaged and sufficient corrosion resistance to withstand attack by atmosphere and finger perspiration.

Nine steels have been procured for use in this study and tests are under way to establish the optimum conditions of hardening and refrigeration to obtain the desired hardness and dimensional stability. Promising results have been obtained in nitriding samples of 410 stainless steel with ammonia.

High-Strength Alloys. Following the development, under the sponsorship of the Navy Bureau of Aeronautics, of an ultra-high-strength steel suitable for use in aircraft landing gears at ambient temperatures, attention is now being directed toward the development of a high-strength steel for use at moderately elevated temperatures.

Currently, there is widespread interest in steels having tensile strengths of about 250,000 to 300,000 lb/in.^{2} at room temperature, for aircraft construction. However, their fatigue strength is often not much higher than that of steels having much lower static strengths and this fact has tended to discourage their more extensive use. Research is continuing in this area to provide information on the metallurgical conditions that will produce steel having the optimum fatigue strength.

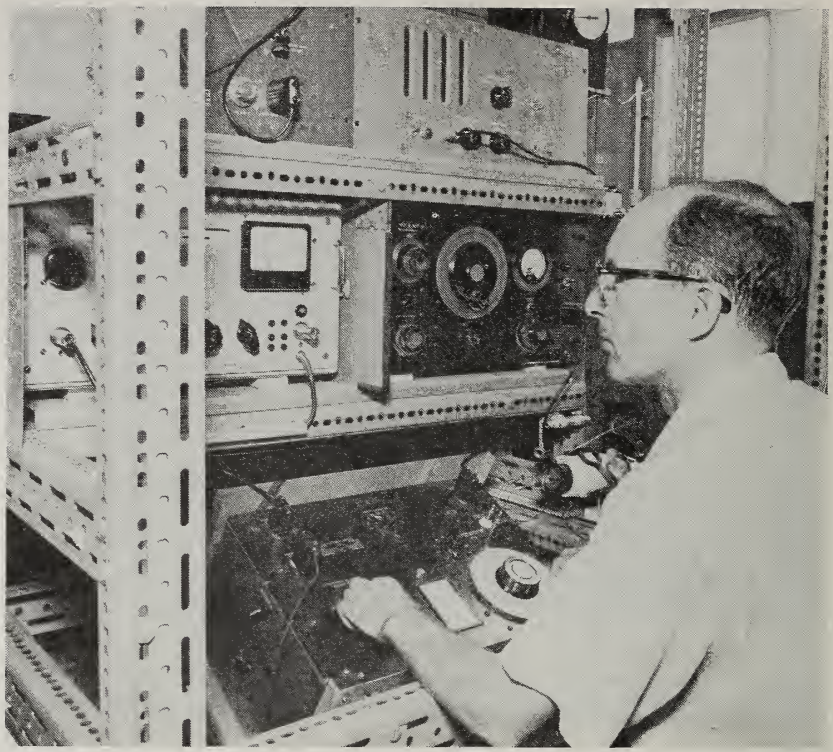
Titanium and its alloys have such high strength-weight ratios that they are now being used in increasing amounts in military aircraft and airborne equipment. Information is needed on their mechanical properties as affected by stress concentrations, stress systems, and by subzero and moderately elevated temperatures in order to use this relatively new class of structural materials to the best advantage. A study was, therefore, made to evaluate the behavior in tension of annealed commercially pure titanium and a 4-percent aluminum–4-percent manganese titanium alloy at temperatures ranging from −196° to +100° C under stresses such as those induced by a circumferential V-notch in cylindrical specimens. The experimental results showed that the resistance to flow increased in both the metal and the alloy with either a decrease in test temperature or an increase in notch depth. The increase in resistance to flow, however, was accompanied by a corresponding decrease in ductility.

Stainless Steels. The precipitation-hardening stainless steels are now being widely used at tensile strength levels of from 175,000 to 200,000 lb/in.^{2} in aircraft construction where the components attain moderately elevated temperatures. The 17-percent chromium–7-percent nickel precipitation-hardening type, known as 17–7 PH, retains at 800° F about 75 percent of its strength at room temperature. The aircraft industry is now in urgent need of structural steels having even higher strength levels in order to meet the continuing demand for increase in speed and performance. The 17–7 PH steel can be heat-treated and refrigerated to produce tensile strengths at room temperature in excess of 200,000 lb/in.^{2}, but this increase is accompanied by a decrease in ductility. As this type of stainless steel is relatively new, the mechanism of hardening is not well-understood, and the identity of the hardening compound and the optimum conditions for heat treating have not been definitely established. A study is now being made for Wright Air Development Center of the effects of various combinations of heat treatments on the mechanical properties of this steel at room and elevated temperatures.

The stress corrosion of austenitic stainless steels is currently being studied with the support of the Pressure Vessel Research Committee of the Welding Research Council. It has been shown during the past year that stress cracks occur only after some plastic deformation while the steels are being exposed to a corrosive medium.

2.9. Mineral Products

The Bureau conducts both fundamental and applied research on a wide variety of inorganic materials. These materials are of interest to the nonmetallic mineral industries in the production of refractories, porcelains, pottery, glasses, enamels, cermets, and cements. The primary objective of this work is the accumulation of basic data on the properties, constants, and behavior of these materials as an aid in advancing tech-



Recent studies of dielectric materials led to a new method of representing dielectric data. This method, which makes use of the complex conductivity is easier to interpret at low frequencies than previous methods (p. 57).

nological development in the ceramic industries. Particular attention is given to those areas of research which are most applicable to all branches of the industry.

Studies of the properties and behavior of materials at high temperatures were continued because of the urgent need for such basic information in work on atomic energy and high-speed flight. Much of the special equipment required for working at high temperatures, including a solar furnace, has been assembled and is currently being used to obtain data on the chemical, physical, and engineering properties of refractory oxides and oxide systems.

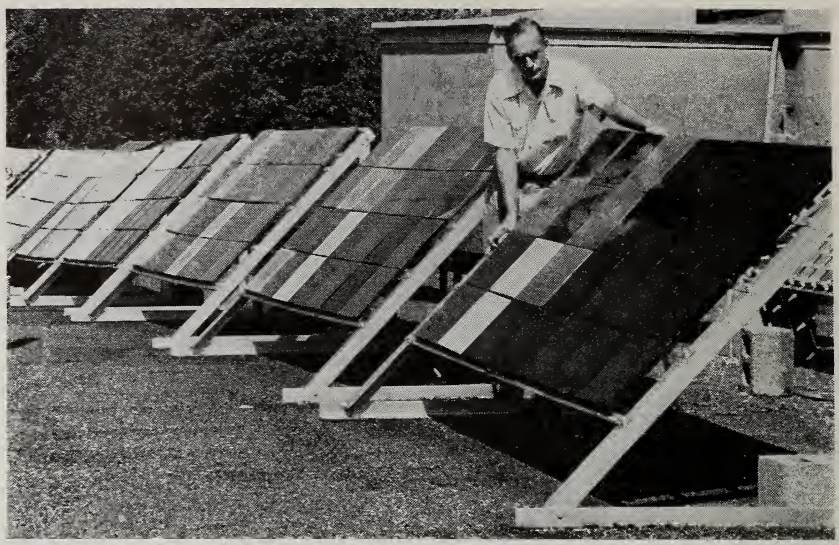
Spectra of Calcium Silicates and Aluminates. Infrared absorption methods were utilized to investigate the complex chemical and physical structure of the calcium silicates and aluminates which are believed to be responsible for the hardening of portland cement. To study the changes produced by hydration, absorption spectra were obtained on laboratory-prepared compounds of tricalcium silicate, beta-dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite, both before and after hydration. Preliminary measurements of calcium silicate hydrate, prepared from tricalcium silicate, indicate that the OH bending frequency occurs at a longer wavelength than in most other hydrates.

Structure and Ferroelectricity. A study of a dielectric relaxation process occurring at low frequencies in ceramic barium titanate led to a new method of representing dielectric data. This new method, which uses the complex conductivity rather than the complex permittivity, is easier to interpret at low frequencies than are previously used methods.

A method was developed for the resolution of overlapping X-ray diffraction peaks. The Fourier coefficients of the unresolved doublet are determined and then used to calculate the coefficients for the individual components. In its present form, the method requires prior knowledge of the relative heights of the individual components and assumes that they have the same unknown but symmetrical shape. Current work is concerned with removing the need for this prior knowledge.

In multidomain barium titanate crystals the domains possess random orientation. In so-called single-domain crystals all domains have the same orientation. The process of converting multidomain crystals into single-domain form is important in preparing memory elements for computers and in establishing the piezoelectric properties of ferroelectric ceramic transducers. Normally this conversion is carried out at the ferroelectric Curie point at 120° C. During the past year it was found that conversion could also be effected at the transition between ferroelectric states at about 0° C. From a practical standpoint this may be important because the higher electrical conductivity at the higher temperature makes the conversion process somewhat uncertain. It was also found that the orientation of the domains could be controlled during conversion at 0° C. Thus it is now possible to prepare crystals completely in what is known as the *a*-domain form. The availability of crystals in this form should make possible an extension of the knowledge of the domain properties of barium titanate.

Phase Relations in System Lime-Alumina-Water. The aqueous system lime-alumina-water has been the subject of numerous investigations, largely because of its importance to the setting and hardening of cementitious materials. Knowledge of the solid phases in this system, and their stability relationships, is essential to an understanding of portland cement, aluminous cement, and the various types of slag cements. Despite the wealth of existing data, certain aspects of the subject are still in doubt. In an attempt to clarify these aspects an investigation is being conducted at lower temperatures than have been previously employed in this work. Monocalcium aluminate hydrate, hitherto an uncertain entity, has been prepared sufficiently pure and in adequate crystal size to permit determination of its composition and optical properties. It has been shown to be an essential constituent of hydrated aluminous cements. Tricalcium aluminate hexahydrate, the only ternary phase in the system that is stable from room temperature up to 200° C, appears not to be stable at 1° C. At this temperature, it slowly changes to one or more of the hexagonal hydrates. On the basis of as yet incomplete data, the solid phases stable at 1° C appear to be hydrated alumina (gibbsite), calcium hydroxide, and tetracalcium aluminate hydrate.



15-year weather-exposure study of porcelain enameled steel panels was completed. Measurement of changes in gloss and color were used to evaluate the weather resistance of various types of enamel (p. 59).

Vaporization Processes at High Temperatures. A knowledge of the factors governing the behavior of refractory materials at high temperatures is important to the success of guided missiles, high-speed planes, and atomic reactors. For example, in the temperature range of 1,500° to 2,500° C, the vapor pressure of solids and their vaporization process under the influence of surrounding gases play a dominant role in determining the volume stability of the solid or its general usefulness as a structural component.

Equipment has been constructed for carrying out vaporization studies of inorganic refractory oxides using the Langmuir or weight loss technique. In this technique the vapor pressure can be determined by following the changes in weight with time of a solid of known area at some constant temperature. The vapor pressure of aluminum oxide has been determined in the range 1,000° to 1,350° C. With the recent installation of a 50-kw induction heater this temperature range can be extended to 1,900° C.

Preliminary studies of the vaporization process of aluminum oxide in the presence of various gases are under way. When the temperature of aluminum oxide was raised to its melting point (2,015° C) in the Bureau's solar furnace, the alumina volatilized at such a rate that the molten material appeared first to boil and then to freeze as it drew upon its own heat to maintain the volatilization process.

Excess Entropy of Glass. The molecular structure of many different types of glasses is under comprehensive fundamental study. Determining the basic principles can make possible the full development of potential uses for glass which are not yet completely exploited. One such possibility is the extensive use of glass as a structural material. This study

is concerned with the molecular analysis of the reaction of glasses to mechanical vibrations over a wide range of frequency, the presence of incidental minor constituents such as water in glasses at high temperatures, and the excess entropy of compounds in the glassy (vitreous) condition when compared with the same compound in the crystalline form.

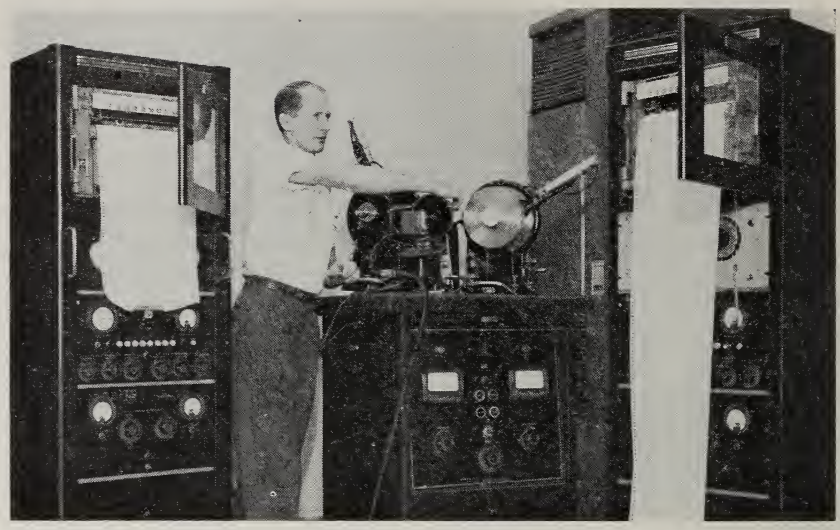
Excess entropy is a measure of the extent to which the molecules in a glass are disorganized rather than being orderly arranged as in the crystalline form. This disorganization is a common feature of all glasses, and may be a controlling factor in many of the desirable properties peculiar to glasses.

Excess entropies are being studied by calorimetric determination of the residual entropies of glasses at temperatures near absolute zero. Another technique compares the entropies of vaporization of corresponding glasses and crystals obtained through vapor pressure measurements at several temperatures. A series of vapor pressure measurements has been completed on vitreous arsenic trisulfide at temperatures between 120° and 180° C by a transpiration technique. This technique requires the collection and measurement of the amount of experimental material in a known volume of carrier gas (nitrogen). A number of experiments suggested that the values obtained represent an equilibrium vaporization process, since the vitreous condition is not usually considered to be one of thermodynamic equilibrium.

High-Temperature Properties of Silica. Silica (SiO_2) is one of the most important of the refractory oxides. It can exist in several distinct crystallographic forms depending on the temperature of heat treatment. The transformation from one form to another involves a volume or density change which may be detrimental to the strength and volume stability of the refractory.

There are wide gaps in the understanding of the fundamental nature of these transformations. For example, cristobalite, the high temperature form of silica, has a rapid reversible transformation with accompanying undesirable volume change in the range 180° to 270° C. The higher the temperature of heat treatment, the higher this inversion temperature. This effect is anomalous since such an inversion should occur at a fixed temperature. Current work with a highly purified source of silica has shown that its inversion temperature above 1,500° C is constant. Silica heated to lower temperatures has a lower inversion temperature which is apparently related to a larger number of defects or lower degree of crystallinity. Indications are that the effect of higher temperature heat treatment is to perfect the structure as reflected in a constant transformation temperature.

Properties of Porcelain Enamels. Analysis of the data taken during a 15-year weather-exposure test of porcelain-enameled steel panels was completed. At the request of the Porcelain Enamel Institute, the study has been extended, with provision for continued inclusion of new types of enamels as they become important.



Standard X-ray diffraction patterns prepared by the Bureau provide industry with a rapid means for identifying crystalline materials (p. 61).

Evaluation of color-differences among groups of similar porcelain enameled specimens was completed. This program involved analysis of visual estimates made by more than 30 individuals in 8 different laboratories. The results will be compared with several types of instrumental measurements, and will be useful in establishing a standard color-difference test.

Analysis of extensive field service and laboratory data, taken over periods of 5 to 7 years on porcelain-enameled fixtures, has been continued. Experimental laboratory tests were made in an effort to develop test methods that would give better correlation with service results than existing tests do, and that would be suitable for adoption as standards.

Thermochemistry of Cement Compounds. As part of the Bureau's program of determining the properties and constitution of materials, measurements have been made of the heats of formation of compounds occurring in cements and their hydration products. Since the compounds in the cementing materials occur in a finely divided state, surface energies contribute significantly in their formation. It is important, therefore, to study the finely divided cementing materials as well as their major constituents. A knowledge of the thermodynamic properties of these compounds is necessary to determine their stability relationships and in gaining an understanding of their behavior.

During the past year, heat-of-reaction studies have been made on the high-sulfate form of calcium sulfoaluminate. This compound appears to be important to the setting process of portland cement, plays a part in the destructive action of sulfate waters on concrete, and is a major constituent of supersulfate cements. Studies have also been made of hardened pastes of calcium hydroxide, silica gel, and water. These are the ultimate products of the hydrolysis of portland cement.

Special Optical Glasses. The use of infrared devices for missile guidance, target detection, aerial mapping, and fire control is constantly increasing. In the production of a material having the desired properties for infrared application, glasses offer many advantages. Their optical and physical properties can be varied over a considerable range by appropriate composition changes. They can be shaped by molding, grinding, and polishing without the necessity for cutting or cleaving in a particular direction as is the case with crystals.

Under the sponsorship of the Navy Bureau of Ordnance, research has been conducted on such simple ternary glass-forming systems as BaO-TiO_2-SiO_2, BaO-La_2O_3-SiO_2, and BaO-Ta_2O_5-SiO_2. The objective of this investigation is to find glasses having good transmittance in the infrared, high refractive indices at these wavelengths, high deformation temperatures, and good chemical durability. Based on the ternary compositions, multicomponent glasses have been developed which have good infrared transmittance, refractive indices up to 1.99, deformation temperatures above 800° C, and good stability in aqueous solutions of moderate acidity or alkalinity. Three glasses developed for the Navy are now being melted in pilot production by a commercial producer.

The calcium aluminate glasses have been under study. They transmit well in the infrared, but usually have poor durability when exposed to moist atmospheres. Samples of improved glasses are now being tested to determine if the durability is satisfactory for conditions of actual use.

Spalling of Concrete at Elevated Temperatures. During the warm-up and take-off periods of jet aircraft, concrete aprons are often observed to deteriorate rapidly, even explosively, as a result of the extreme thermal shock. To find means of preventing such failures some of the factors affecting the thermal spalling characteristics of concrete are being investigated for the Navy Bureau of Yards and Docks.

Results showed that the primary cause of concrete spalling under rapid thermal shock is related to the total amount of unbound water present in the concrete. The rate and amount of water that is absorbed by concretes has been determined as a function of the mode of preparation, type of aggregate employed, and porosity of the hardened mass. Wide variations in both the rate and amount of water absorbed and returned were observed, depending on the type of aggregate used. The available pore space or degree of consolidation in the aggregate has been found the dominant factor in the selection of a proper aggregate.

Standard X-ray Diffraction Patterns. In close cooperation with the Joint Committee for Chemical Analysis by X-ray Diffraction Methods, a continuing program is contributing standard X-ray diffraction patterns for the powder data file, widely used in research and industry as a rapid means for identifying crystalline materials. During the past year 53 standard patterns were published, replacing 62 cards in the file and adding 7 new compounds. Further improvement of the quality of X-ray patterns is now being sought, through elimination of scattering caused by general radiation.

Crystal Structure of Inorganic Materials. Additional data have been obtained on the crystal structure of inorganic materials. The correct formula and crystal structure of the triclinic form of magnesium pyroborate ($Mg_2B_2O_5$) have been determined. The formula had been incorrectly reported as MgB_2O_4 and, independently, an incorrect structure had been proposed. Three-dimensional data were obtained and analyzed by structure factor and Fourier calculations; atomic parameters for the boron in the pyroborate group were determined.

The crystal structure of $BaHPO_4$ has also been determined. The results are of interest because in spite of the presence of the heavy barium atom, it was possible to locate the position of the H atoms approximately.

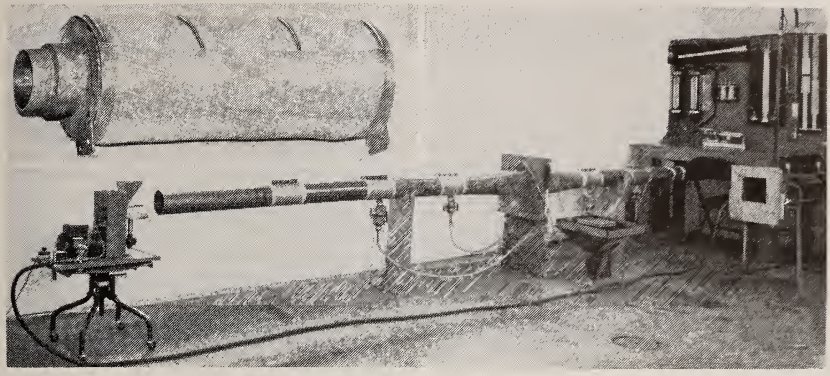
2.10. Building Technology

The building technology research program is concerned primarily with determining the properties of building materials and structural elements. It also includes pertinent research in establishing adequate standards of measurement, new testing procedures, and performance standards. The program is designed to provide the Government, the building industry, and associated professions with fundamental technical data useful in the preparation of building codes, standards, and engineering design criteria.

In the fire protection field, emphasis was on the study of flammable behavior of materials, and methods for measuring and characterizing these properties. New techniques of standardization and test methods are being developed for refrigeration and air-conditioning, particularly for heat transmission into mechanically refrigerated enclosures. A study of the surge-flow characteristic of horizontal drains in plumbing systems has been initiated and the results should prove useful in establishing new code values. The lightning hazards of ungrounded metallic roofing, siding, and reflective insulation are also under investigation.

Several long-term programs are still continuing. Among these are studies of asphalt deterioration, of the resistance to shear and bending of reinforced concrete beams containing new types of deformed reinforcing bars, and of the effects of moisture in roof insulation.

Design Stress in Reinforced Concrete. Since the first use of reinforced concrete there has been a constant trend toward higher design stresses. There is at present great interest in more efficient utilization of the new types of deformed reinforcing bars which have been developed by the steel industry. Adequate data on these bars have not been available to designers and code-writing organizations for determining proper design stresses in reinforcing bars. To provide the needed data, a research program has been conducted in cooperation with the American Iron and Steel Institute to determine the effect of variations of the design stresses in the reinforcement on the flexural rigidity of beams, widths of cracks, and resistance to diagonal tension. This information is intended to enable designers to estimate the load-carrying capacities and to ascertain the manner of failure of concrete beams with reinforcement of the new type.



Test apparatus used in designing air cleaners for helicopters. This investigation resulted in a dry cloth cleaner (insert) which removes more than 99 percent of the dust from the carburetor intake of small aircraft. The device is made of four layers of heavily napped acrylic fiber fleece and weighs about 3 pounds (p. 63).

Cracks in Reinforced Concrete. The width of tensile cracks that normally develop in reinforced concrete beams can be reduced by using well-designed deformed bars which develop high bond-strengths. Recent work at the Bureau has demonstrated that the crack width at the surface of a deformed bar is significantly less than the width at the exterior surface of concrete. These results were observed on tensile bond-specimens which simulated a segment of the tensile portion of a reinforced concrete beam between two successive cracked sections.

Air Cleaners for Helicopters. At the request of the Office of the Chief of Transportation, Department of the Army, the Bureau has been investigating methods for removing dust from the carburetor intake air of small military aircraft. Excessive wear of helicopter aircraft engines operating in dusty areas indicates that none of the commercial air cleaners now in use meet all the requirements of filtering efficiency, dust holding capacity, light weight, and easy serviceability.

Information was gathered on dust characteristics, such as particle-size distribution and maximum concentration in air, from airfields in different parts of the world. Dust samples were collected at various locations around helicopters landing in or hovering over dusty areas. These samples were analyzed for dust concentration and particle-size distribution.

The most promising development resulting from this study appeared to be an air filter employing four layers of a heavy commercial napped acrylic fiber. This filter meets all of the requirements, and a prototype is being constructed for flight tests.

Metering Heat Sink for Refrigerated Enclosures. Ice accumulation in the insulated space of a refrigerated trailer increases the heat transfer rate through the walls and makes the enclosure more difficult to cool. To determine the effect of such ice accumulation, a 21-foot refrigerated semitrailer was operated for about three months in an ambient condition

of 110° F and 60-percent relative humidity with an interior temperature of 0° F. About 850 pounds of ice formed in the insulated space during the first 72 days of this test, and the heat transfer rate increased about 8 percent. These observations were significant to the trucking industry in two respects: First, the amount of ice formed in the insulated spaces was greater than would have been expected for static tests; and second, the effect of the ice on the over-all heat transfer rate was less than expected. An inspection of the insulated spaces of the vehicle after the 850 pounds of ice had accumulated showed that most of the ice was formed in the roof and upper part of the sides of the trailer. The moisture transfer mechanism which produces this formation is currently being investigated.

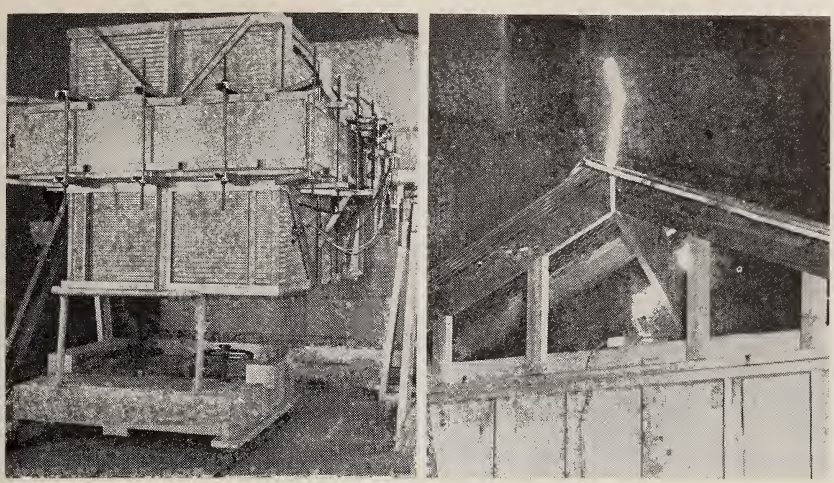
A metering heat-sink apparatus was developed for this study. The ability of this device to record promptly the change in over-all heat transfer was of great interest to the trucking industry. Therefore, a Government-industry research project has been initiated to develop a prototype metering heat sink apparatus and to establish test conditions that can be adopted as a standard method for rating the heat transfer of commercial refrigerated trailers. The laboratory test method will be designed to produce ratings that can be used to predict actual in-use performance, and road tests of several vehicles will be made to indicate the validity of the laboratory rating.

Standards for Built-Up Roofs. Field studies of asphalt and coal-tar pitch built-up roofs were made in the Eastern, Western, and Mid-Western States at the request of agencies of the Department of Defense. In all areas, numerous roofs of both types were found that were still in good condition even after more than 20 years of service. A proposed purchase specification was prepared for asphalt for use in the construction of mineral-surfaced, built-up roofs on slopes not greater than 1 inch per foot, based largely on laboratory studies of 14 samples of asphalt submitted by roofing manufacturers.

Asphalt Roofing. Work has continued on the degradation of asphalt during weathering. The most fruitful results during the past year have been obtained by determining the effect of heat, light, and water, and of heat alone, on component distribution during the exposure.

Under study were the variables pertinent to the durability of three asphalts in combination with 14 mineral additives. Among these variables were softening point of the asphalts, concentration of additives, thickness of coatings, particle size and shape, and degree of mixing. In general, it was shown that the asphalt was the most important constituent in a stabilized coating and that mineral additives with plate-like particle shapes were most effective in increasing durability.

Thermal Insulation with Reflective Surfaces. A study of the thermal insulating value of air spaces with metallic reflective surfaces was completed. Earlier studies had indicated that the insulating value of these spaces with metallic surfaces was considerable, especially for applications in which heat flow is downward.

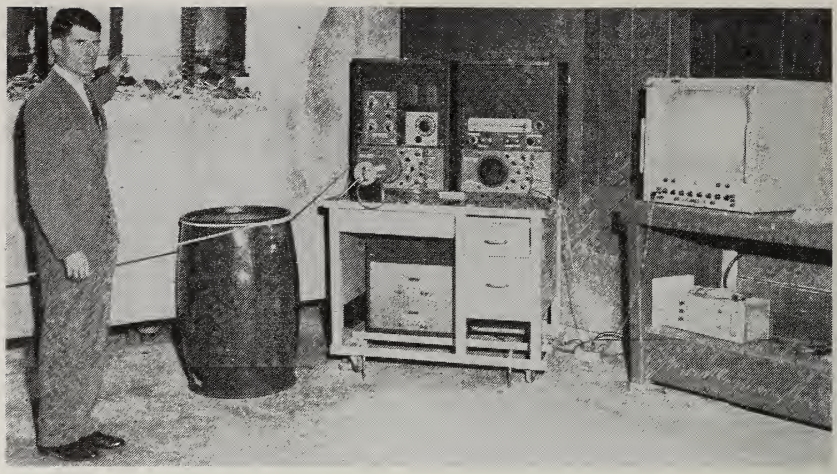


Left: **Equipment used to study the heat-insulating value of fibrous insulation provided with reflective surfaces (p. 64). Known as a rotatable guarded hot box, the assembly consists of two enclosures with an insulating test panel interposed between them.** *Right:* **Structure used for lightning studies of ungrounded metal-roofed buildings (p. 62).**

The earlier studies provided data for calculating values of reflectively insulated air spaces. Insulation manufacturers then wanted to know what improvement would result if fibrous types of insulation were provided with reflective surfaces. In order to investigate this and allied problems, additional research was undertaken, with partial financial support by the Aluminum Company of America. In this investigation, the additional insulating effect obtained when reflective surfaces are applied to fibrous insulations was measured experimentally. An important phase of the work was the comparison of the experimental values with those calculated from the data provided earlier.

Analyzer for Transient Heat Flow. A device that rapidly solves problems of transient heat flow in solids was completed. It is an electrical analog comparator based upon the similarity between the differential equations of electrical circuits and those of the time-variable flow of heat. The device is especially designed for convenient application to a variety of problems of heat flow in materials and building constructions. Temperatures can be computed in various parts of the construction at different intervals following the exposure of one side of the structure to heat, according to any chosen schedule.

The analog comparator derives its speed from applying a voltage to the electrical network at a rate 4 million times that at which the corresponding temperature would be applied to a structure in a fire resistance test. The immediate use of the comparator will be to study the effects of a variety of design variables on temperature gradients in structures undergoing fire resistance tests.



Transient heat-flow analyzer designed to eliminate costly large-scale fire tests by analyzing data about thermal properties of materials (p. 65).

Mechanism of Fire Extinguishment. During initial phases of investigating the mechanisms by which dry chemical powders may be effective in controlling fires, it became evident that improved methods of measuring and controlling the characteristics of dispersed powders were required. Three new methods have been devised in this program sponsored by the Bureau of Ships. Two of these relate to the effectiveness of the chemicals in suppressing fires while the third involves a new means for measuring the dispersible characteristics of powders. Dispersibility is a function of particle size and shape and of the tendency of particles to agglomerate, all of which appear to affect the usefulness of a powder as an extinguishing agent.

2.11. Applied Mathematics

The Bureau maintains a central applied mathematics facility which conducts basic and applied research and renders advisory services in the various mathematical fields that are germane to the Bureau's mission. The services of the applied mathematics laboratories are available to other Government agencies as well as to the Bureau's technical staff. Equipped with high-speed digital computers and other modern computing aids, the facility has played a significant supporting role to the Bureau's research and development program.

During the past year, research emphasis was again placed on statistical and numerical analysis, and on mathematical physics. Special assistance was rendered to the Bureau staff and other Government groups in these areas and in digital computation. In addition to consulting services in mathematical statistics and other branches of applied mathematics, extensive attention was given to problem formulation and analysis to select and, if necessary, develop numerical methods suitable for the solution of

problems on automatic and nonautomatic computing machines. A wide range of investigations and applications in engineering and the physical sciences was covered. In addition, an increasing share of the mathematical program was devoted to applications of digital computers to problems of the type encountered in business management and operation, sometimes referred to as "data processing" problems.

Again, as in previous years, the Bureau's applied mathematics program was strengthened by the active interest and support of other Government agencies. Especially significant was the support of fundamental and applied research in numerical analysis and mathematical physics by the Office of Naval Research and the USAF Office of Scientific Research. The National Science Foundation entrusted the Bureau with two important new undertakings in the field of mathematics: The compilation of a Handbook of Mathematical Tables and a training program in numerical analysis for university staff members.

Numerical Analysis. Considerable effort was devoted to the planning and delivery of a training program in numerical analysis for senior university staff, which was supported by the National Science Foundation. The objective of this program was to provide intensive training in numerical analysis for university teachers who are experts in related mathematical fields and who aspire to teach and conduct research in numerical analysis and to direct university computer centers. The present national shortage of mathematicians competent in programing for high-speed automatic digital computers and in carrying out the required numerical analysis has motivated the presentation of a concentrated course in the subject. Few university staffs have sufficient experience in the field to qualify them to give appropriate instruction and direction of research. Also, unless trained staffs are available, the high-speed computing equipment now being acquired by many institutions may be misused. The present program aims to help fill these needs.

In addition to its prime purpose, the training program has enabled the Bureau staff to make a survey of the whole field of numerical analysis. This has revealed some areas in which development is urgently needed. As a result, the way has been opened to several new productive areas of research.

A considerable effort at every computing center has gone into the preparation of codes for the inversion of matrices which occur, for example, in the solution of sets of linear equations. The question of what is the best code, either generally, or for a particular class of matrices (well-conditioned, ill-conditioned, sparse, full) is difficult to answer theoretically. To attack this problem empirically, a representative selection of 12 matrices was made and some of their characteristics were studied theoretically. Then the selected matrices were inverted on high-speed computers using what were felt to be the best available codes. In each case various measures of the errors committed were recorded. A comparative study of these results, and similar ones which it is hoped will be produced by

other computing centers to whom the matrices have been sent, should give some indication of the most efficient inversion codes. With these results as a guide, further investigation of these codes will then be undertaken.

An intensive study was made of matrix theory—in particular, of inequalities for the eigenvalues of matrices and the eigenvalues of sums of noncommuting matrices. Matrices with nonnegative elements, which include stochastic matrices (widely used in statistics), have been especially studied.

Mathematical Tables. A comprehensive plan was drawn up for a handbook of mathematical tables. The need for such a handbook was originally discussed at the Conference of Mathematical Tables held at Cambridge, Massachusetts, in 1954 under the auspices of the Massachusetts Institute of Technology and the National Science Foundation. The project is an outgrowth of the recommendation of the conference that the NSF support the preparation of a handbook by the Bureau.

Expected to contain about 1,000 pages, the handbook will cover the entire field of special functions, giving formulas, graphs, and mathematical tables. It will contain 28 chapters on such topics as mathematical and physical constants, powers and roots, elementary and higher transcendental functions, in addition to basic tables for combinatorial analysis, numerical analysis, and statistics.

Computations continued on other mathematical tables of widespread interest and importance to the chemical, physical, and engineering sciences. The tabulation of L-shell conversion coefficients was completed; and further editing was done on the tables of the exponential integrals for complex arguments, modified Airy integral, and Sievert's integral. Also, a table of Coulomb wave functions which covers the range of interest in current nuclear problems was prepared.

Digital Computation. The Bureau's computation laboratory serves the Bureau staff and other Federal agencies in the analysis and solution of mathematical problems, especially those involving electronic computation. It also develops general-purpose techniques of programing and coding for automatic computing machines and publishes mathematical tables of general utility.

A major development in computational facilities was the installation of an IBM 704 computer in May, 1957. This machine, one of the most modern commercially-available computers, is a powerful addition to the available tools for solving highly complex scientific problems by numerical methods.

Spectrum analysis computations were successfully programed on SEAC and established as a routine problem; and a start was made on programing these computations for the IBM 704. Crystal structure calculations were continued in the determination of so-called *d*-spacings. New programs for crystallographic calculations on SEAC were used successfully and have been substituted for some phases of punched-card work.

Installation of a second high-speed digital computer facilitated the solving of scientific problems by numerical methods (p. 68).

Computations for other Bureau laboratories were also carried out on a continuing basis on SEAC and the IBM 704 in the following projects: Evaluation of thermodynamic functions, thermometer calibrations, optical ray tracing, analysis of noise measurements, stresses in a wall foundation, calculation of transmission-delay times, ground-wave attenuation, stresses in a wall resting on a footing, crystal field effects for atoms, collision integrals used in transport theory, NBS payroll, nuclear diffusion calculations, and basic ionospheric data.

Statistical Engineering. The principal function of the statistical engineering program is to advise the Bureau's scientific and technical personnel on the application of modern probability and statistical methods in physical-science and engineering experimentation. The aim is to assist the scientist conducting research, development, or testing programs so that conclusions of desired scope and reliability may be attained at the lowest possible cost under existing limitations of funds, equipment, materials, and personnel. During the year extensive services were rendered, ranging from short informal conferences to active collaboration with project leaders for periods of several months.

To maintain and increase the effectiveness of this program, basic research in probability theory and mathematical statistics was conducted. During the past year, this research, geared to fit the particular needs of NBS laboratories, fell into two categories: Planning (design) of experiments, and methods for analyzing data.

Research was continued on a family of experimental arrangements known as fractional factorial designs. Factorial designs, complete or fractional, are widely used for carrying out experiments that involve many different factors. During the year, a catalog of fractional factorial designs for experiments having all factors at two conditions was published as Applied Mathematics Series 48. A large number of designs were also constructed for experiments having all factors at three conditions.

A method of data analysis was developed to permit the use of a large existing class of incomplete block designs for factorial experiments requiring several repetitions of each combination of factors. Other research in the theory of experiment design consisted of a uniqueness proof concerning a class of incomplete block designs, and a set of necessary and sufficient conditions for the existence of fractional factorial designs having certain prescribed properties.

A large research project was initiated on the mathematical and statistical aspects of the definition, measurement, and specification of the reliability of components and assemblies, with particular attention to the evaluation of the reliability of electronic components and systems.

Mathematical Physics. Most of the fields of applied mathematics which are important in theoretical physics and the engineering sciences are covered in the Bureau's research program in mathematical physics. Attention is given especially to fluid dynamics, elasticity, and electromagnetic field theory. Also, the supporting mathematical methods used as tools in these fields are studied in a general way.

In fluid dynamics, a study of two-phase flows, such as flow in a mixture of steam and water, is under way. These problems occur in important engineering and military applications, such as the design of steam jets and of high-temperature cooling systems. Also, a study of airflow about a ring-shaped wing in the presence of an axially symmetric body was started and the flow of a compressible fluid past a wedge was analyzed.

In elasticity, new results were obtained on the reaction of an elastic cone to forces acting on its surface. Vibrations of delta wings, used on supersonic aircraft, were studied in detail; experience was gained with the application of finite-difference methods to this problem. An earlier study of the bending of corrugated diaphragms was broadened. Computations were carried out on the geophysical problem of the static deformation of the earth under gravitational forces. Research in the propagation of electromagnetic waves resulted in new expressions for the fields of spherical, cylindrical, and plane waves diffracted on wedges, in terms of integral representations.

In the study of supporting mathematical methods a table of Fourier transforms of probability distribution functions was compiled and prepared for printing. Also, new graphical methods were developed for the rapid solution of several types of ordinary differential equations.

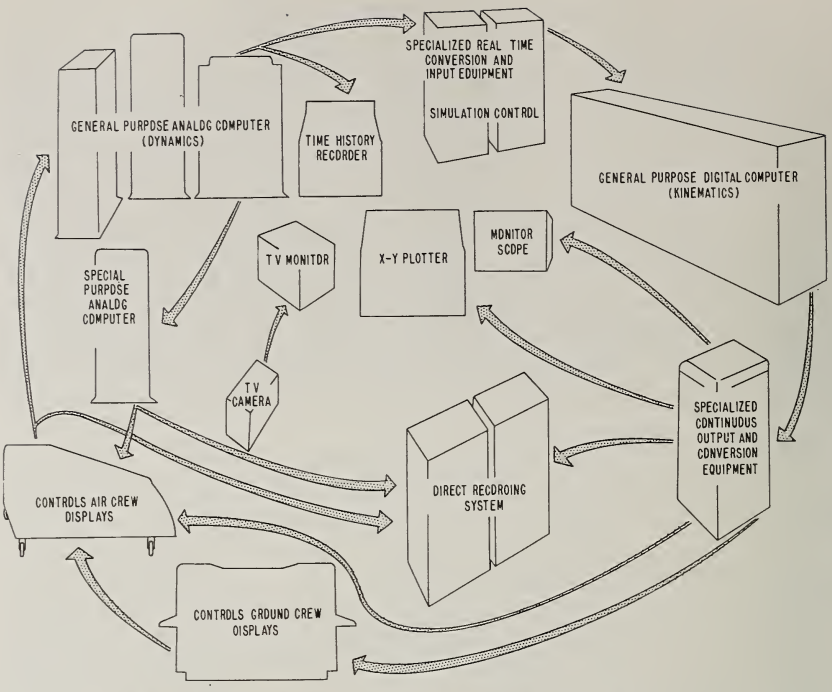
2.12. Data Processing Systems

The data-processing systems program encompasses research, development, systems design and analysis, and technical advisory services in both digital and analog-computer technology. This program originated during the postwar years as a result of requests from several Government agencies for assistance in evaluating the potential application of automatic electronic digital computers to their problems and in procuring suitable installations. These studies, from which systems specifications were established, eventually led to the Bureau's program of research and development of improved computer components and circuitry, and subsequently to the design and construction of SEAC, the Bureau's high-speed digital computer. Since 1950, SEAC has established an impressive record of solutions for both scientific and management problems for the Bureau and other Government agencies.

Today, the data processing systems laboratory provides a comprehensive and readily available Government source of information in the new and rapidly growing field of high-speed automatic data-processors and control systems. An increasing number of other Government agencies are seeking the Bureau's technical advisory services on high-speed digital techniques in new areas of potential application, such as massive paperwork operations, mechanizing of postal operations and patent searching, control systems, and simulation, as well as in the solution of specific technical problems.

SEAC. More than 7 years of operation, most of which has been on a round-the-clock schedule, have been completed. During this time, SEAC has been used mainly as a computational facility for problems originating within the Bureau. At the end of the fiscal year, however, it was changed to a research facility for data-processing applications and an engineering tool for studies of components and systems. Preparation for this new role has been under way during the past year. Circuitry for new input-output devices has been installed. New high-speed multichannel tape units, perforated paper tape readers, tape perforators, and an alphanumeric printer have been procured; and a scanning device for pictorial input has been incorporated into the machine. Conversion circuitry for use of an additional mercury memory unit of 512 words has been completed. The procurement and installation of an input-output staticizer have made possible direct communication of the SEAC with an analog computer.

Components and Techniques. New components and techniques have been under investigation for performing such basic operations as switching, storage, and input-output in digital data-processing systems. One result has been a set of switching circuits that: (1) Uses the fastest switching transistor that is in quantity production; (2) is economical in the number of transistors used; and (3) tolerates almost the entire range of variation of production-line transistors. The circuits use saturating Eccles-Jordan flip-flops and single-transistor two-input and-gates. They are being tested in an experimental diode-capacitor memory system.



Flow chart showing how interconnecting analog and digital computers together with display equipment can be used to simulate complex systems in which human operators comprise serial elements in control loops (p. 74).

A diode-capacitor memory that stores 256 words and operates on a 1-microsecond cycle has been developed for use with the high-speed arithmetic unit in a pilot data processor. Another diode-capacitor memory that stores 64 10-bit words and operates on a 2-microsecond cycle has been designed with completely transistorized circuits. The purpose of this memory is to gain operating and life experience on both the transistors and the circuits. Work has also been initiated on the evaporation of thin films of magnetic alloy for a coincident-current magnetic memory.

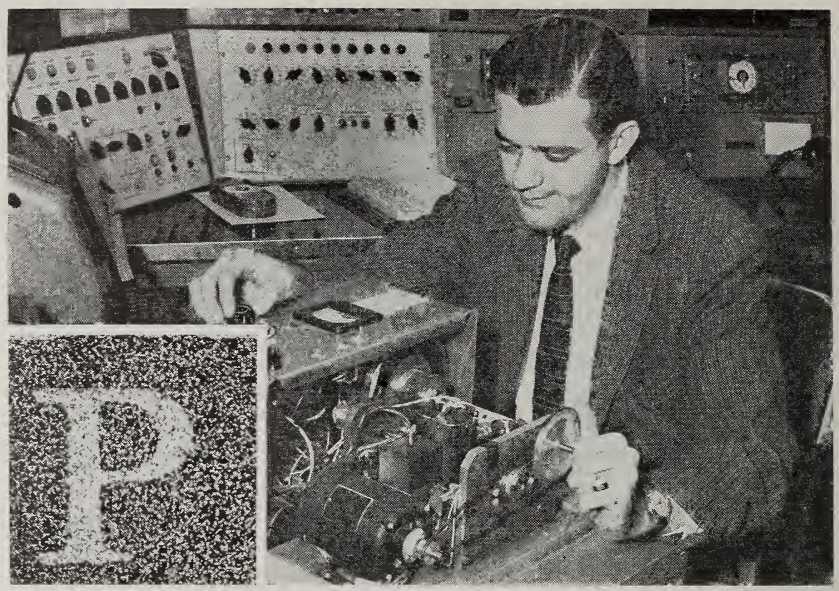
Computer Circuit Packaging. Progress was made in the further development of a low-power vacuum tube computer package under sponsorship of the Air Force Cambridge Research Center. A family of such units has now been completed. These etched-circuit units are compatible with each other and can be interconnected in many ways to perform complex arithmetic and control functions. There are four types of packages: Single amplifier tube with logical gates, two amplifier tubes with logical gates, delay line, and indicator. The packages work at a basic repetition rate of 1 megacycle per second in a 5-phase system. This essentially permits a 5-megacycle per second processing rate. Except for testing in larger arrays, the engineering design has been completed. Production runs of these packages will be incorporated eventually in the pilot data processor being designed by the Bureau.

Magnetic Tape Devices for Input-Output. Because of the massive data files required for a project on mechanization of patent search (page 71), the present magnetic-tape facilities of SEAC must be expanded. To this end, 8 multichannel tape-transport units were purchased, tested, and modified for improved performance. Completely transistorized circuits for reading and writing on tapes were designed and a prototype chassis built and tested. Suitable circuitry for tape-unit selection is being designed to activate the 8 tape units simultaneously so that they can run concurrently on sample data retrieval problems.

Pilot Electronic Data-Processor. The Bureau has been developing design specifications for a large-scale pilot electronic data-processor. This computer will carry out experimental investigations of a wide variety of large-scale data-processing problems of particular importance to the Government. Realistic test runs on large-scale data reduction, record-keeping, and information retrieval problems present stringent operating requirements beyond the scope of presently available equipment. Because of this wide range of application, the new data-processing system must combine into a single installation a number of different characteristics not ordinarily associated with one machine, i. e., high-computation rate, flexibility of communication with external devices, and a wide variety of internal processing operations. The major functional units for the data processor have now been fully blocked out and component quotas established for most of the important portions of the system. Detailed functional designs have been developed for all of the critical units and procurement of high-priority components has begun.

Advanced Computer Systems. Many urgent computing and control problems call for faster and more powerful digital systems with much higher problem-solving capabilities than currently available machines can provide. To this end, the logic of processing operations common to both mathematical calculation and data-processing manipulation has been under study. A series of designs has been developed for a general-purpose arithmetic and processing unit based on a modified version of a previously designed high-speed binary adder. The new unit operates at essentially the same speed as the earlier one, but its computing properties have been extended. New classes of possible operations include: (1) Interchangeable decimal and binary arithmetic using the same equipment without need for special conversion units, (2) fixed-point and floating-point operations in both decimal and binary notation, (3) automatically interchangeable word formats with different selected degrees of precision. As a result, a number of design improvements have been incorporated into the plans of the NBS Pilot Electronic Data-Processor. These improvements should contribute substantially toward increasing its over-all versatility and problem-solving power.

Transistor Magnetic-Core Circuitry. Transistor magnetic-core circuitry for switching applications offers such useful characteristics as compactness, low power, reliability, and ruggedness. The basic parameters of these



Automatic scanning equipment which enables a digital computer to accept an image from a photograph or drawing into its memory (p. 75). The computer can then either reproduce a facsimile copy from its memory or display the image as modified by internal processing (insert).

components were studied for the Air Force Cambridge Research Center to find the cores and transistors most suitable for electronic-computer application. A single repeater stage and a recirculating flip-flop were designed and studied for possible development of a computer module.

Control Systems and Simulation. Interconnecting analog and digital computers together with display equipment permit simulation of complex systems in which human operators comprise serial elements in control loops. A model-simulation facility has been developed for optimizing a complex man-machine system in a project for the Wright Air Development Center. This equipment will first be used to simulate the flight of a manned supersonic aircraft with ground control and to provide prompt computation of the data for quantitative analysis.

Schematic diagrams have been devised for three other special-purpose analog systems—one for collision prediction and prevention in en route control of air traffic, one for simulating jet engines for purposes of preproduction analysis, and one for warning against crane overturn.

A function generator to handle two independent variables was designed and constructed to interpolate between six function generators of a single variable. Its operating speed is about 100 cycles per second and linearity of interpolation is approximately 1 percent.

Computations were carried out on the analog computer for a seismeter, transistor diode-amplifier, betatron particle, supersonic aircraft, thermo-hydraulic test-unit, war game, missile trajectory, log-exponential equa-

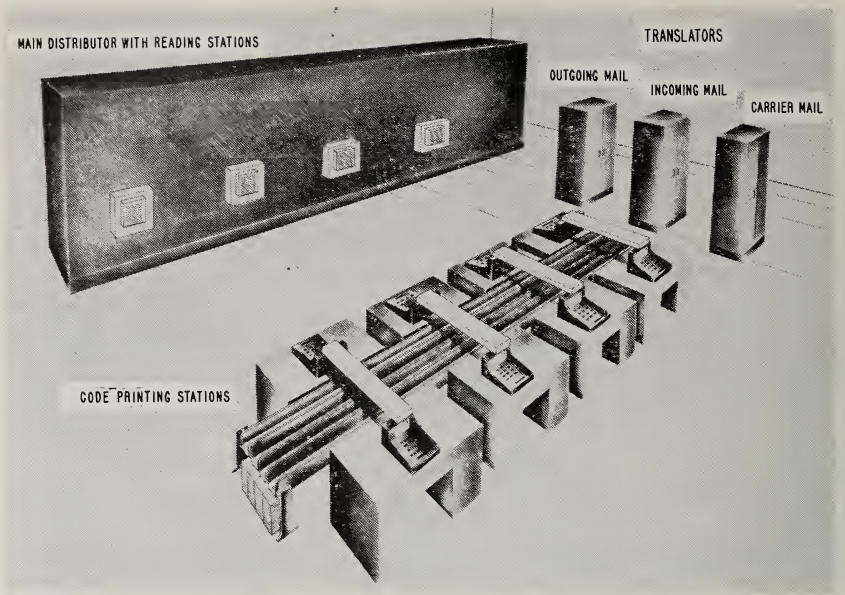
tion, DATRAC, VANGUARD, and copper-cyanide equilibrium. The feasibility of analog computations was investigated for problems dealing with tristimulus color values, flame temperatures, space charge in a tetrode, transistor flip-flop, eigenvalues of a 4×4 matrix, radar tracking, insect population, electron optics, and magnetic field mapping.

Data Processing Applications. Studies were under way on data-processing problems common to various Government agencies, on the development of special patent-search procedures, on mathematical and linguistic techniques applicable to problems of information retrieval, on a survey of automatic character-recognition devices, and on the design and development of automatic scanning-equipment for direct input to SEAC of graphic and pictorial information.

Analysis and programing of a typical payroll and leave accounting problem for a Government agency resulted in a successful application from which extrapolation to payroll requirements in other agencies should follow. Technical advice and assistance in problem analysis, formulation of machine-performance requirements, and evaluation of system proposals were provided to the Treasury Department in connection with the mechanization of the issue and redemption of savings bonds, and to the Government of Puerto Rico for a general business management application. In addition, SEAC was used to explore the feasibility of using automatic data-processing equipment to check the eligibility reports of occupants of 400,000 units of low-rent housing under Public Housing Administration jurisdiction.

Considerable progress was made in a cooperative program with the Patent Office for the mechanization of patent search operations. A general-purpose SEAC routine was developed for the search of topological structures, and applied to an element-by-element search of chemical structures. This routine has been used for sample searches of steroid patents. A comprehensive machine-search procedure was developed for general searches of patents pertaining to the composition of matter. New techniques of mathematics, logic, and linguistics that may be applicable to the solution of complex problems in information retrieval were explored, including the development of a machine program to investigate the syntactical structure of a variety of English sentences.

Under the sponsorship of Rome Air Development Center, automatic scanner input- and output-display equipment was designed and constructed to enable experimental simulation on SEAC of various character-recognition logics. This equipment makes it possible for a digital computer to accept automatically an image from a photograph or drawing into its memory and to reproduce a facsimile copy from its memory or to display the image as modified by internal processing. SEAC programs have been written to determine experimentally, various criteria for character and pattern recognition. These include routines to determine and display the center of gravity of an input image and to determine the boundaries of black areas.



Artist's conception of one section of a mechanized post office. The Bureau is developing equipment and techniques to accelerate mail sorting (p. 76).

Processing First-Class Mail. Work was continued on the operations analysis of mail handling in post offices with the specific aim of developing automatic equipment and techniques for improving the present sorting operation. Studies of letter characteristics and mail distribution have been made in varying detail for several large cities. Several special plans for address coding have been developed and tested prior to final evaluation by actual use of equipment designed to simulate an operator coding station. Possibilities for computer analysis of coding plans to develop unique designation codes have been explored and programing is in process. In addition, sorting machines suitable for use in both large and small post offices are under development.

2.13. Cryogenic Engineering

The primary objectives of the Cryogenic Engineering Laboratory are to obtain information needed for the practical applications of very low temperatures and to assist Government and industry with problems in this special field.

To carry out these objectives, the Laboratory conducts research on the properties of materials at low temperatures, cryogenic processes, and cryogenic equipment. A large demand for advisory services to both industry and other Government agencies has been created by the greatly increasing interest in engineering applications at very low temperatures.

During the past year, an important part of the Laboratory's work involved planning of large-scale hydrogen liquefaction and pumping

facilities. It was found that a dual pressure process for hydrogen liquefaction has many unique advantages when compared with other better-known processes. These findings should have an important bearing on plant design.

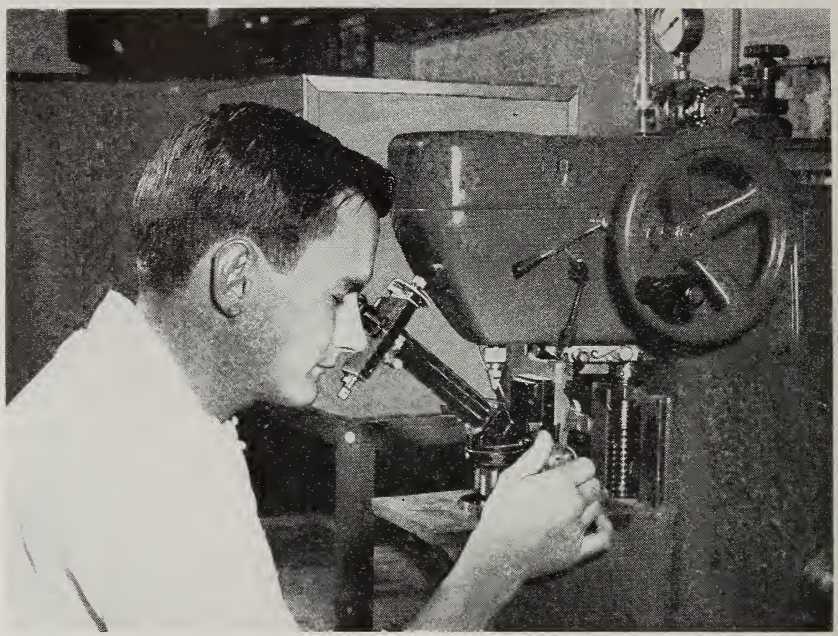
A successful but limited experimental investigation showed that adhesives have wide potential utility in bonding or sealing structures for low-temperature application where other techniques such as welding are inapplicable. Investigations recently completed of the low-temperature characteristics of selected commercial metal-bonding adhesives indicate that further research along basic lines may lead to substantial improvements.

Operation of crystal frequency standards at low temperatures promises to reduce drift of crystal characteristics with time (aging), and also permits more precise realization of the resonant frequency. The resulting improvement in precision with which standard frequencies can be maintained is of importance in maintaining time standards and in certain navigational systems. However, a critical problem is the maintaining of an accurately controlled temperature environment for the crystal oscillator. A laboratory cryostat has been built to evaluate methods of holding quartz crystal oscillators at accurately maintained low temperatures for long periods of time. In initial tests it has regulated within about 10^{-4} degree at both 76° K and at ambient temperature.

Low-Temperature Properties of Materials. The thermal and electrical conductivities and the thermoelectric power of a series of commercial aluminum alloys and a pure aluminum have been measured and are being analyzed in the light of current theory. An earlier program on coppers has been rounded out by additional measurements and is being published. These data are of importance in both the applied and basic fields. They will be valuable in the future design of cryogenic equipment and will shed light on the mechanisms for the transport of heat and electricity in metals. The wide variation found among the thermal conductivities of commercially pure coppers has shown designers of cryogenic apparatus the necessity for careful selection of this metal.

Tables of the integrals $J_n(x)=\int_0^x y^n dy/(e^y-1)(1-e^{-y})$, of greater range and accuracy than previously available, have been prepared by automatic computer and are being published. These integrals find wide use in interpreting and correlating transport and thermal properties of solids.

A new apparatus for intercomparing resistance thermometers, thermocouples, vapor-pressure thermometers, and the helium-gas thermometer has been built and put in service. It is also adaptable to measuring electrical resistivity and thermoelectric power of metals. It has been used to establish the calibrations of thermocouples using gold-cobalt alloy. These thermocouples are finding a rapidly expanding field of use in both engineering and research as practical low-temperature thermometers of intermediate accuracy.



Measurements of the mechanical properties of metals and alloys are important in determining their suitability for low-temperature applications (p. 78).

Measurements of the electrical resistance of various pressed or soldered contacts between copper have shown that it is not difficult to make low-loss connections to heavy-duty conductors of this metal. Even at 20° K, where the resistivity of copper can be extremely small, little difficulty was encountered. This finding is of interest to designers of powerful electromagnets for operation at the temperature of liquid hydrogen.

Methods have been devised for bonding wire-resistance strain gages to metals that are to be subjected to cryogenic temperatures. Calibrations of such gages have been made down to 4° K. The success of this technique permits considerable simplification of the instrumentation customary in stress-strain measurements on structural metals for cryogenic applications.

Measurements of the tensile and yield strengths, and of Young's modulus for a number of nickel alloys and austenitic stainless steels have been completed down to 20° K. These alloys are widely used in low-temperature applications because of their maintenance of ductility under a wide range of conditions.

In a continuing project on thermal insulations some commercial plastic foams, a large number of specially prepared foams, and some additional evacuated powders were evaluated. The heat conductivities of these materials are critically important in determining the thermal efficiencies of cryogenic devices which they insulate (for example, vessels for the storage or transportation of liquid oxygen or hydrogen). An inexpensive

aluminum-perlite mixture has been found that is comparable to any evacuated powder used previously as insulation.

Cryogenic Processes. Research on the separation of gases by low-temperature techniques is continuing. Data obtained from recent experiments were applied to the design of a pilot column, 6 inches in diameter, for the separation of deuterium from normal hydrogen. Using cryogenic distillation methods, studies have been made of the separation of argon and helium from natural gas, and of all 6 isotopic modifications of hydrogen.

In cooperation with the University of California Radiation Laboratory, work is continuing on the design and construction of a 500-liter liquid hydrogen bubble chamber. Plans have been completed and control methods evaluated for a hydrogen refrigerator having a capacity of 1,800 watts.

In support of the continuing development of efficient ortho- para-hydrogen conversion in very large hydrogen liquefiers, studies were made with both laboratory and plant-scale converters. It has been previously established that hydrous ferric oxide granules constitute a highly efficient ortho-para-conversion catalyst. Data are now available covering the use of this catalyst for both liquid and vapor phase conversion. These data make possible the design of converters at all temperatures normally encountered in hydrogen liquefaction cycles.

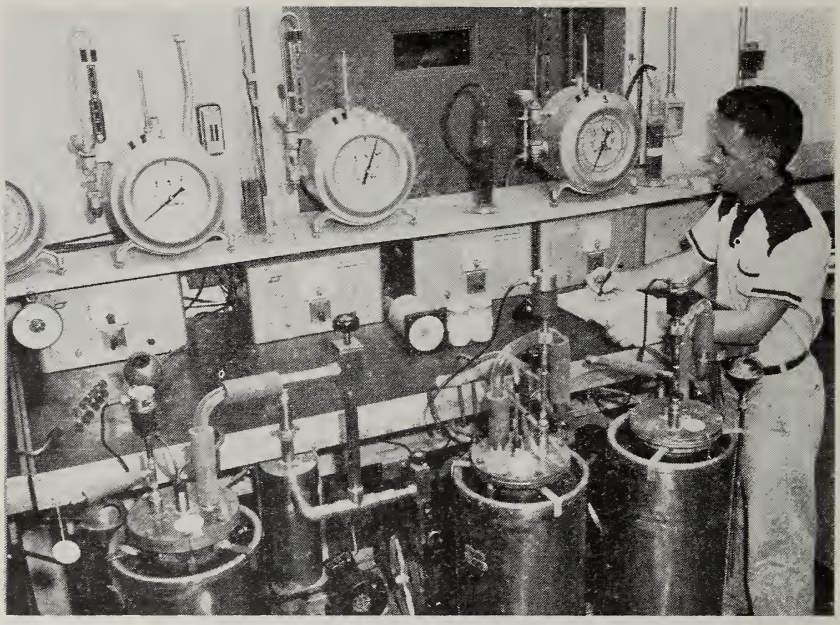
Because the design of large hydrogen gas-purification equipment appears to require more data on low-temperature adsorption than are now available, a project has been undertaken to measure adsorption capacities of various substances. In conjunction with this project, gas-analysis techniques are being studied and an effort is being made to develop a very sensitive instrument for analyzing trace impurities in hydrogen gas.

The Bureau continued to assist the Navy Department in its plan for the liquefaction and distribution of helium. Studies of suitable transportation equipment are now progressing.

Cryogenic Equipment. Experiments are being continued to obtain information on the flow of boiling liquids. A comprehensive experimental program on trichloromonofluoromethane was completed and the data are being correlated.

A permanent pump-testing facility was completed, and extensive data were obtained with an aircraft fuel booster pump in liquid hydrogen and liquid nitrogen. Because common methods for measuring net positive suction head (NPSH) are not accurate enough with liquid hydrogen, a very simple and direct method for measuring this quantity was devised. Also, because the NPSH is strongly dependent on the ortho-para composition of liquid hydrogen, a continuous ortho-para analyser with ten times the sensitivity of previous instruments was designed and built.

In a program to evaluate bearings at low temperature, it was shown that ordinary ball bearings with steel retainers can run at 3,000 revolutions per minute with negligible load for as long as 650 hours submerged in



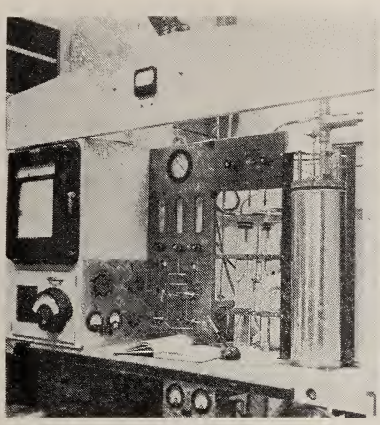
Cryogenic engineering investigation of heat insulation (p. 78). The low-temperature insulating value of specially selected powders is measured by noting the rate of gas evolution from calorimeters.

liquid nitrogen before the retainers fail. However, lives of more than 200 to 300 hours probably should not be expected. Ball bearings with plastic retainers are now being systematically evaluated.

It has been demonstrated that from an economic point of view, liquid oxygen transfer systems associated with the testing of rocket engines should be insulated. Furthermore, if the initial cost of such systems can be amortized over a period of about 2 years or more, high vacuum insulation should be considered.

A detailed analysis was made of the problems encountered in the optimization of 50-gallon air-transportable liquid-oxygen servicing containers. Experimental investigations are now under way. Two promising techniques yet to be evaluated experimentally are: (1) The use of plastics as support members in liquefied gas containers, and (2) the use of the powder in evacuated powder insulation to take shock and impact loads.

Investigations to determine the maximum heat transfer to liquid hydrogen and liquid nitrogen flowing in narrow annular passages have been completed. The results show that: (1) For given flow rates and passage size, liquid nitrogen can dissipate more energy than liquid hydrogen; (2) for natural convection with both liquid hydrogen and liquid nitrogen, a log-log plot of maximum energy that can be dissipated versus the cross-sectional area of the passage is a straight line; (3) the ability to transfer energy to the liquid can be increased by forcing the liquid through the passage; (4) for a given flow rate, the change in the maximum power dissipation with changing passage size is not monotonic.



Left: **Apparatus for evaluating catalysts for converting ortho- to parahydrogen (p. 79).**
Right: **Container for liquid parahydrogen. Development of ortho-para converters in hydrogen liquefiers has made such containers, without auxiliary refrigerators, practical (p. 82).**

Gas Liquefaction. Approximately 150,000 liters of liquid parahydrogen, 850,000 liters of liquid nitrogen, and 800 liters of liquid helium were produced during the year. Also, about 160,000 standard cubic feet of pure hydrogen gas and 330,000 standard cubic feet of pure nitrogen gas were supplied the Bureau and other agencies. Some of the largest liquid-hydrogen runs ever made were conducted this year. Most of the liquid helium was produced by a small Collins-type liquefier; however, some liquid helium was produced in an experimental, liquid-hydrogen precooled liquefier. The general practice of recovering boil-off hydrogen gas from storage and liquid transfer netted approximately 700,000 cubic feet of hydrogen gas for re-use in the hydrogen liquefaction runs.

The development of the liquid-hydrogen precooled helium liquefier is progressing, but is still in the experimental stages. The latest version of this type of helium liquefier, which will use both liquid nitrogen and liquid hydrogen as precoolants, is under construction. This liquefier is designed to produce 15 liters of liquid helium per hour.

A modification to the hydrogen liquefier was made to accommodate the newly developed iron hydroxide ortho-para catalyst, and also to increase the output of the plant by converting to 95-percent parahydrogen only that hydrogen which was transferred to the storage Dewar. The modification involved changing to two Joule-Thomson valves and using a condensing heat exchanger located in the liquid-hydrogen bath. This heat exchanger also contains the iron hydroxide catalyst chamber. Practically all of the liquid hydrogen produced during the year was made in this modified liquefier with very satisfactory results, including an increase of approximately 9 percent in the production rate of 95-percent parahydrogen.

In addition to the production of liquid hydrogen, nitrogen, and helium, numerous experimental full-scale runs were made to obtain information

on the adsorption characteristics of silica gel purifiers. The runs were made under various operating conditions and differing nitrogen impurity levels in the hydrogen gas. This work is still in progress and a large amount of valuable data is being obtained. Also, experimental runs are in progress to evaluate the feasibility of using vapor phase ortho-para converters at liquid nitrogen temperature in large-scale hydrogen liquefiers. Results thus far indicate that a parahydrogen level of 50 to 51 percent can be obtained with an iron hydroxide catalyst maintained at 71° K in the hydrogen purifier nitrogen bath. In effect, this arrangement has increased the output of the hydrogen liquefier by approximately 7 percent.

2.14. Radio Propagation

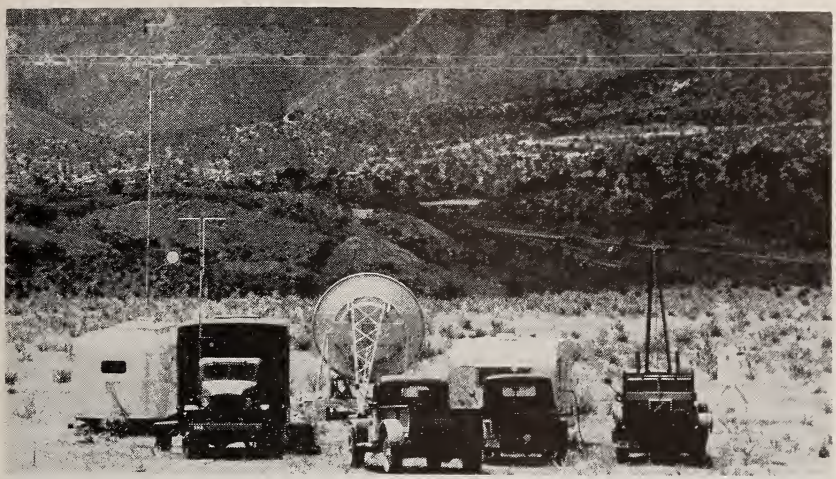
The Central Radio Propagation Laboratory has primary responsibility within the Nation for collecting, analyzing, and disseminating radio propagation data and information of value to such diversified fields as air and sea navigation, frequency allocation, and worldwide communications. To carry out this responsibility, the Laboratory conducts research on the fundamental nature of radio waves, the basic theories of radio-wave propagation, and the characteristics of radio energy under widely varying conditions. A network of field stations is operated from the Arctic to the tropics, and data are exchanged with other laboratories throughout the world. Within the Central Radio Propagation Laboratory are two divisions, Radio Propagation Physics and Radio Propagation Engineering.

Radio Propagation Physics

The radio propagation physics program is concerned with radio wave propagation over long distances by means of the ionized regions of the earth's outer atmosphere. The program includes: (1) Basic research on upper-atmosphere physics, on the formation and disturbances of the ionosphere, and on the interaction of radio waves with the ionization; (2) study of the characteristics of specific propagation mechanisms such as ionospheric reflection, ionospheric scattering, and guided-mode propagation; and (3) regular public service as in the prediction of long-term changes in useful frequencies for communication, in the warning of short-term disturbances to communication, and in the collection and distribution of ionospheric and solar data on a national and international basis.

Participation in the International Geophysical Year. A large part of the Bureau's activities in radio-propagation physics during the past year has been devoted to the International Geophysical Year of 1957–58. From observation stations widely scattered over the globe, the Bureau has begun collecting data on many phases of upper-atmospheric physics and radio-propagation physics. Research is under way on properties of the ionosphere, forward-scatter propagation, various kinds of radio noise, airglow, and related phenomena.

The preparatory work for establishing special communication circuits for IGY-propagation research has been completed. In one experiment,

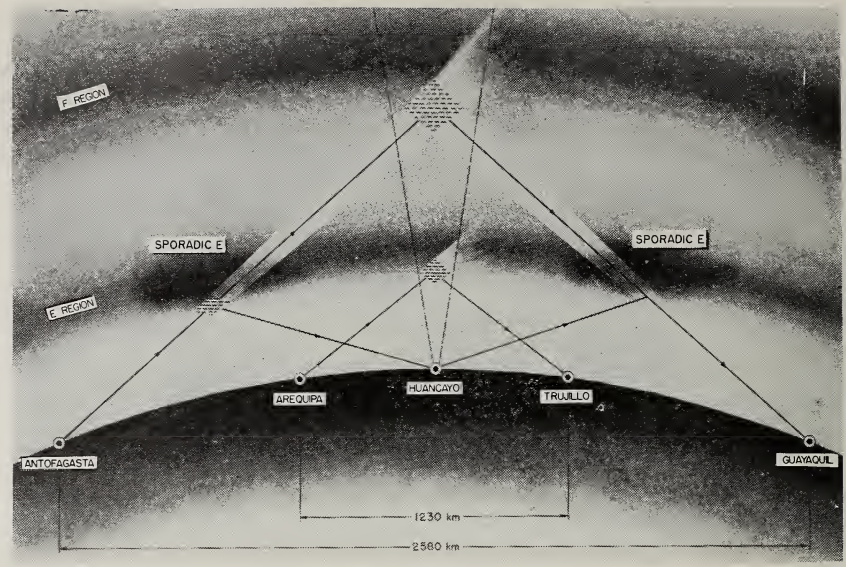


Experimental setup for measuring variations in radio wave propagation over a long air path (p. 82).

a study is being made of the scattering of radio waves from the lower portion of the *E*-region in the vicinity of the magnetic equator. At the same time, a search for possible scattering from the lower *F*-region is being carried out. This work includes establishing stations in Chile, northern Peru, southern Peru, and southern Ecuador, and cooperatively working with stations operated by other countries in central Peru, Argentina, and Brazil. Four mobile stations have been specially equipped for this program, and at the end of the year were undergoing field tests preparatory to shipping to South America.

The Bureau's radio forecasting center at Fort Belvoir, Va., was selected as the IGY World Warning Agency. This agency makes the final decisions designating the IGY Alerts and Special World Intervals which are flashed in a few hours to IGY stations throughout the world. One aspect of this program has been the assembling of the most extensive communications network ever used for scientific purposes. With the activation of the Agency, the telegraphic reporting of significant solar, ionospheric, and related data was increased tenfold so that all outstanding phenomena of significance for geophysical experiments can now be made known in less than 24 hours. The short-term radio propagation forecasts, an NBS service of many years, have benefited greatly from these improved arrangements.

Another major activity for the IGY is an experiment to determine the comparative behavior of "sporadic-*E*" ionization in the Eastern and Western Hemispheres. Analyses of existing data make it appear that ionization is much more intense in the Far East than in the Western Hemisphere. Circuits are being established in the Philippines and Okinawa, in the Panama Canal Zone and Cuba, and in the central United States to obtain more information on this phenomena.



Experimental radio paths being installed in South America to study radio scattering from the ionosphere during the International Geophysical Year (p. 83).

Design and construction of an airglow telescopic photometer for use throughout the Western Hemisphere during the IGY was completed, and an additional airglow observatory was established. Preliminary work was carried out on one of the World Data Centers for ionospheric physics and for airglow. This Center will serve as a permanent repository and a distribution proof for data from all countries in these disciplines.

In carrying out a program for the vertical sounding of ionospheric characteristics, equipment was provided for a number of new stations established by the United States and for most of the new ones established by South American countries. Personnel were located and trained for vertical incidence stations on the Antarctic continent, and assistance was given to several South American countries in training their personnel and establishing new stations. In cooperation with the Barker and Williamson Company, four units of the new NBS Model C–4 ionosphere recorder were rapidly assembled and tested for early shipment to IGY stations in the Antarctic. Later, an additional 10 units were supplied to other IGY stations.

Origin of Ionospheric Fading. For the first time, an unambiguous explanation was obtained of the fading observed in radio-wave pulses reflected at vertical incidence from the $F2$ layer of the ionosphere. It had not been known previously whether this fading originates mainly near the level of reflection or at some lower level. A "fading origin" experiment showed that the scattering which introduced fading in the case of reflection from the $F2$ layer nearly always took place well below the level of reflection. Under some circumstances an elaboration of this experiment permits the actual height of the scattering to be determined.

Nighttime Ionospheric Reflections. By means of a 3,400-foot antenna strung across a mountain canyon, for the first time concurrent recordings were made of reflections of the ionosphere with sweep frequencies covering the entire range from 50 kilocycles per second to 25 megacycles per second. Analysis of these records is expected to give a better understanding of reflections from the nighttime *E*-region of the ionosphere.

Radio Noise from Jupiter. Radio noise emitted by the planet Jupiter was recorded at 18 and 20 Mc. The analyzed data give strong evidence that Jupiter possesses an ionosphere with a critical frequency in the neighborhood of 15 Mc. Jupiter's ionosphere appears to change with the solar sunspot cycle in much the same way as the ionosphere of the earth. Statistical analysis of the occurrence of the noise not only made possible a precise determination of the rotation period of the planet but also demonstrated that there is a rigid core beneath the optically opaque atmosphere from which the noise originates.

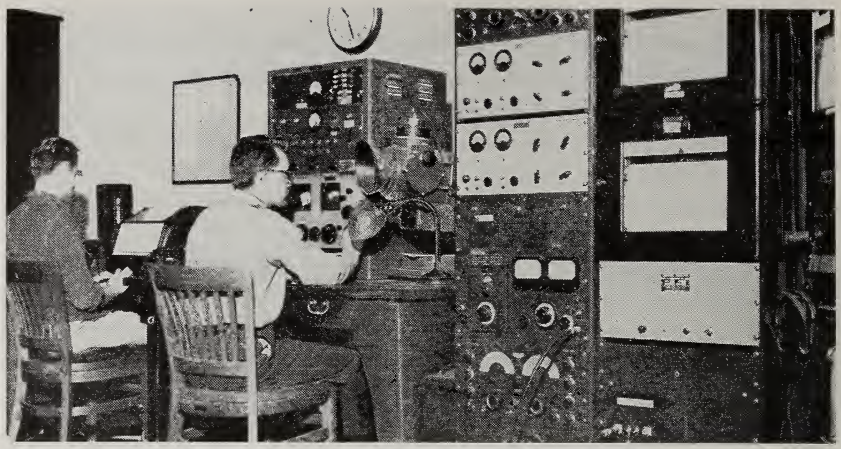
Oscillations in the Earth's Atmosphere. Worldwide oscillations of the earth's atmosphere and the current system resulting from the interaction of the ionized upper atmosphere with the earth's magnetic field were under study. A theory of forced oscillations extended to include frictional losses provided an explanation of the observed quarter-diurnal pressure variation in terms of self-coupling of the large semidiurnal component.

Radio Propagation Engineering

The objective of the work in radio propagation engineering is the more efficient use of the radiofrequency spectrum. This objective can be attained only to the degree that the nature of radio-wave propagation and the characteristics and the effects of radio noise and interference upon various signals are understood both qualitatively and quantitatively. The quantitative understanding of radio-wave propagation and the characteristics of radio noise requires the collection of statistical samples of data appropriate for the description of observed phenomena, and the development of adequate methods for the prediction from these samples of the statistical characteristics of the various radio-wave propagation and noise variables required in engineering applications. The work of the division is directed toward a basic understanding of radio-wave propagation, radio noise, and signal-to-noise problems in general.

Low-Frequency Propagation. Progress was made in developing dependable methods for calculating both steady-state and transient propagation in the range of frequencies from about 100 kc to less than 10 kc. These results have application to communication and navigation systems.

Worldwide Radio Systems Engineering. The Department of Defense requires reliable radio communication systems operating in many parts of the world. In many of these systems, it is planned to use tropospheric scatter propagation. For these reasons, the Bureau has been studying the characteristics of tropospheric scatter propagation on a worldwide basis. These studies have involved determinations of the effects of climate and terrain on radio-propagation conditions, and the preparation of maps of



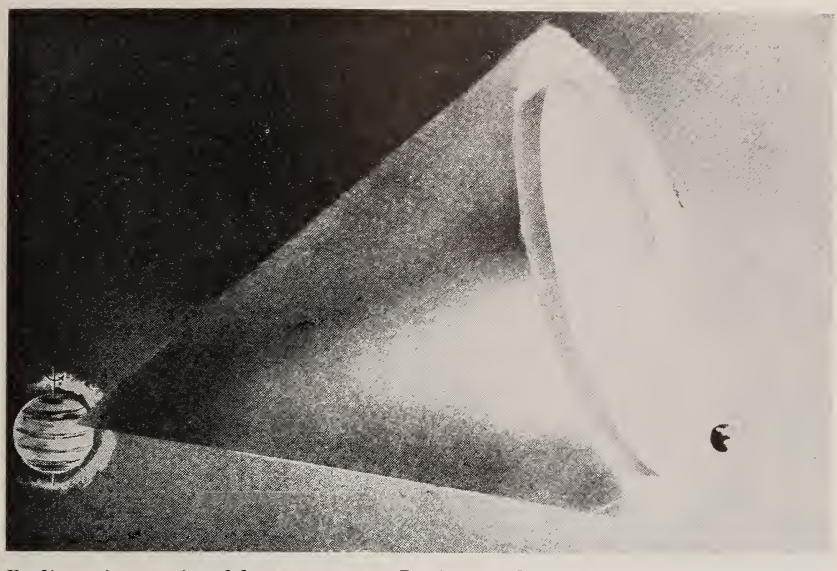
Control room of the IGY World Warning Agency at the NBS radio forecasting center, Fort Belvoir, Va. This station serves as the focal point of a world-wide communications network for the International Geophysical Year (p. 83).

the radio climate to be expected in various parts of the world. The requirements of transmitter power, radiofrequency, antenna size, and communication-channel capabilities are being evaluated.

Tropospheric Forward Scatter Theory. The formula for estimating the transmission loss expected on a tropospheric forward scatter circuit has been improved in several respects. Allowance has been made for obstacle gain. A more accurate allowance has been made for the surface refractivity. The calculation has been extended for communications over greater distances and to higher terminal antennas such as those on airplanes. Moreover, the expected distribution of transmission loss versus percent time can now be calculated for various periods during particular seasons, times of day, or for an entire year. As a result, the formula is now sufficiently accurate so that path-loss tests are generally no longer required prior to installation of a forward scatter system.

Bending of Radio Waves. A quantitative understanding of the bending of radio waves by the atmosphere is important to the successful use of radar height-finding methods, tropospheric forward-scatter predictions, and radio-guidance systems. During the past year, it has been shown that the average bending can be quite accurately predicted when only the surface refractivity is known. These values of the surface refractivity are determined from surface weather observations.

Radio Studies of Atmospheric Turbulence. The Air Force, in its missile-navigation and guidance program, has been interested in determining the potential accuracy of navigation and guidance systems as limited by the effects of the atmosphere. For many years the Bureau has conducted research into the uses and limitations of radio-propagation techniques as applied to these systems. During the past year, experimental studies were made of the factors that influence the velocity of radio propagation on line-of-sight transmission paths. Techniques to measure variations in the



Radio noise, emitted by sources on Jupiter and received on the earth, yields information about Jupiter's physical characteristics (p. 85).

propagation velocity at 1,000 to 10,000 Mc have been developed for this purpose. A part of this study was conducted on the Island of Maui, Territory of Hawaii, where turbulence is very pronounced and various conditions of cloud formations, relative humidity, and wind velocity exist. Analyses of these data have provided information concerning the extent to which radio propagation is affected by atmospheric turbulence. Results of these studies have led to an estimated immediate saving to the Government of approximately $4,000,000 in application to radio systems. The same general techniques are expected to lead to the development of a considerably more accurate distance-measuring system than presently available in geodetics and seismology.

Tacan Investigation. The Air Navigation Development Board requested the Bureau to evaluate the propagation conditions which determine the coverage and interference characteristic of a new system of air navigation, called Tacan, and to make recommendations for its use in the common system of air navigation. Charts have been prepared showing the coverage of a Tacan facility under various conditions, the required distance separation between ground Tacan facilities operated on co-channel and adjacent channel assignments, and the number of channels required for a specific plan of facility locations and area coverage. This study considered Tacan equipment currently being produced and improved versions which may be available within the next 10 years. Bench tests of current Tacan equipment indicated the system's performance where adjacent channel interference is a problem was not as good as originally anticipated. These results pointed the way to improvements in equipment so that sufficient channels might be available for nationwide coverage.

2.15. Radio Standards

The NBS Radio Standards Laboratory is endeavoring to adapt its program to the ever-growing need for new and improved electronic measurement standards. This program consists mainly of basic research and development on national standards for fundamental electrical quantities, measurement techniques, and properties of materials from audio-frequencies through the highest attainable microwave frequencies. These activities support a calibration service and radio broadcasts of the United States primary standard of frequency and time intervals.

Of major significance during the year was the work on atomic frequency standards. Two types of such atomic standards were put into operation for the first time at the NBS Boulder Laboratories. Another area receiving emphasis was the planning and construction of equipment for the new Electronic Calibration Center now under construction.

Attenuation. Radiofrequency attenuators are widely used by industry and the armed services in many types of electronic-measuring instruments and equipment such as signal generators, receivers, field-strength meters, power meters, and test sets. To insure reliable operation of this equipment, the attenuators must be calibrated against accurate standards. The degree of calibration accuracy required has steadily increased until it is now, in general, second only to that of frequency determinations.

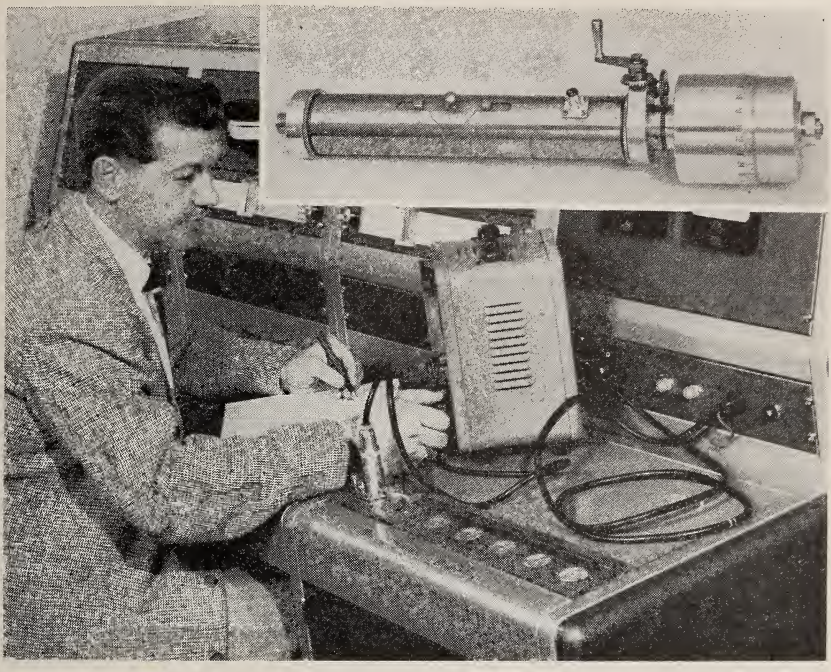
To keep pace with these requirements, theoretical and experimental work was continued on the self-calibrating, high-accuracy, high-sensitivity, insertion-ratio measuring system. This work showed the need for developing ultra-stable components in order to utilize the full accuracy and sensitivity capabilities of the system. A description of the system was prepared for publication.

Further work was also done on the design and construction of a two-channel attenuation measuring system for use in the new Electronic Calibration Center. Theoretical analyses and experimental investigations were made of the interaction effect in the launching and receiving components of waveguide-below-cutoff attenuators. A stable-frequency and essentially constant-current rf power source was constructed.

At microwave frequencies, crystal-mixer linearity in the calibration systems was evaluated. A method of calibration by rf substitution was used to extend the calibration range to 73 db with very little loss of accuracy. Also set up was an improved IF substitution system for coaxial attenuation measurements.

Field-Strength, Noise, and Interference. Standards and uniform measurements of these quantities are necessary to the Government and industry in evaluating the performance, efficiency, and signal coverage of radio communication systems of all types, including AM, FM, and TV broadcasting.

Development, design, and fabrication were essentially completed on 35 special low-noise crystal-controlled receiver converters for 100-, 200-,



One of three rf voltmeter consoles developed to calibrate all types of voltmeters. Unknown voltmeters are calibrated with standard attenuator-thermoelement voltmeters (insert) having reproducibilities of 1 percent or better over a period of 1 year or longer (p. 92).

and 300-Mc use in the Calibration Center; and similar work on 6 converters for 400 and 500 Mc was well advanced.

Other work in this field included: Drawing up of specifications for balancing transformers (range, 1 to 1,000 Mc) and testing samples for use in improving field-strength calibration methods and in balanced-voltage standardization; preliminary study of the feasibility of microwave antenna calibrations; extension of standard microwave noise measurements to new frequencies in the *X*- and *S*-bands; and initiation of a thorough survey of the literature on the standardization of radio interference.

Frequency. Accurate frequency and time standards are of great importance to scientific research laboratories, Government, and industry. Research at the Bureau has reduced variations in such standards by a factor of 10 or more per decade during the last 30 years. As a result, frequencies accurate to 1 part in 100 million and constant to better than 1 part in 1 billion are now available; but even greater accuracy and stability are expected to be needed by science and industry before long.

Research on the stability of quartz resonators at low temperature has therefore been intensified. Theoretical considerations and preliminary measurements indicate that a substantial reduction in frequency aging and frequency-temperature coefficient may be obtained when the temperature of the crystal is reduced. Also, an enhanced *Q*-factor may result.

To obtain more reliable temperature control, investigations were continued on the temperature stability of the earth's crust. Quartz resonators were operated at a 50-foot depth in 4 wells specially sunk for the purpose. To improve frequency-measuring apparatus, research was started on characteristics of frequency multipliers and several improved units were developed. In addition, work was almost completed on an electronic device for using standard time pulses to obtain a gating period for electronic-frequency counters. This device is expected to permit indirect frequency comparisons of WWV with the primary standard to be made more accurately, quickly, and conveniently.

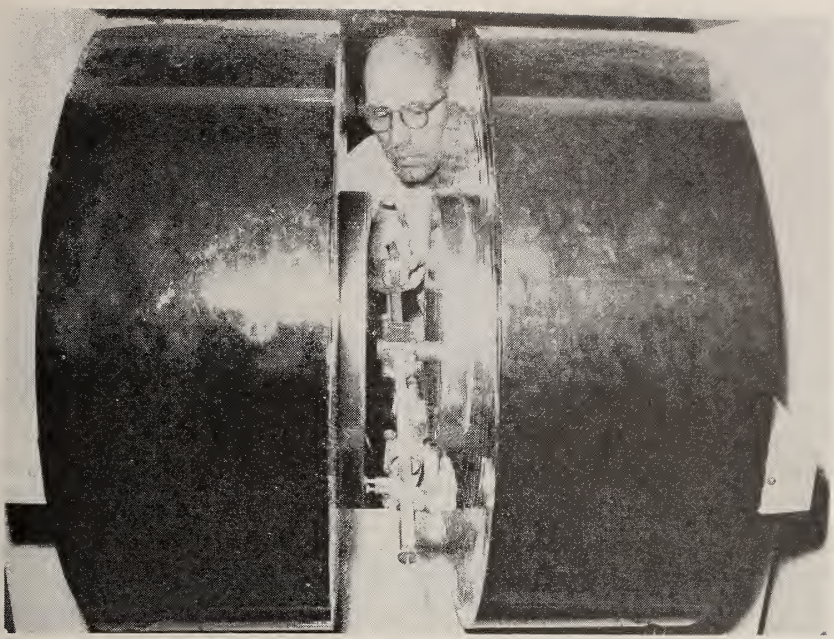
In the microwave frequency range, standards derived from the quartz-crystal primary standard were improved and extended by the use of additional steps in the multiplier chain. With the help of an improved harmonic generator, wavemeters at the higher microwave frequencies can now be calibrated with much less difficulty.

Intensive research on atomic-frequency standards and clocks has been continued. Such standards are believed to be unchanging and therefore may eventually be adopted in preference to the standard of frequency now based on astronomical time observations. The almost instantaneous accessibility of the atomic standard is greatly to be preferred to the long delays necessary in evaluating astronomical data. Possible applications of such standards are great in both number and scientific importance. During the last year, both a cesium-beam spectrometer and an ammonia-beam spectrometer (Maser) were put into operation with a precision of 1 part in 1 billion.

Impedance. The use of resistors, capacitors, inductors, vacuum tubes, transistors, transmission lines, antennas, crystals, directional couplers, and other rf-impedance components has grown to such an extent that the manufacture of these components is now one of this country's major industries. This fact, coupled with the research carried on in the development of instruments and materials for use at these frequencies, has made radiofrequency impedance standards of major importance to the national welfare. In addition, a knowledge of impedance or reflection coefficients, including a recognition of matched conditions in a transmission system, is essential to accurate measurement of attenuation, power, voltage, field-strength, and other quantities.

During the past year, several experimental bridges, designed to improve the efficiency of high-frequency impedance calibration services, were constructed. The calibration of new working standards was continued. Methods were developed for calibrating crystal-measuring equipment and very low impedances.

At microwave frequencies, a paper was prepared on the new type of adjustable sliding termination for rectangular waveguides. Additional work was done to reduce the theoretical solution of the half-round obstacle in a rectangular waveguide to a form suitable for calculation. Further refinements of the coaxial resonance line and associated instru-



A ferrite rod mounted in a cylindrical cavity is placed between the poles of an electromagnet. The microwave electrical constants of ferrites are accurately measured with this equipment (p. 92).

mentation resulted in the first voltage-standing-wave-ratio (VSWR) calibration; and preliminary experiments on a new VSWR measurement technique give promise of a significant improvement in accuracy.

Power. Power is one of the basic electrical quantities for which reliable standards are needed in all frequency ranges. Accurate rf power measurements based on these standards are in wide use by commercial and military groups for both routine operations and special research. Such measurements serve, among other things, to determine the output, range, and proper functioning of oscillators, radar equipment, signal generators, and other devices, and of communication networks such as microwave-relay and scatter-propagation systems.

Further progress was made in developing the electron-beam technique, a particularly promising solution to the problem of accurately measuring microwave high-power and peak-power in a pulsed system. The main source of difficulty in the way of repeatability in the single-beam tube was located and steps have been taken towards elimination of the difficulty. Also, construction of a new four-beam tube was nearly completed.

In regard to other microwave techniques, improvements in the microcalorimeter for the calibration of bolometer mounts have increased its accuracy to 1 percent or better; and experimental tests showed that a thermistor mount is useful for measurements over a much wider range of power levels than the one for which it was calibrated. The self-balancing d-c bolometer bridge was modified to permit operation with thermistors as well as barretters.

From the high-frequency region, the range of the low-power thermistor bridge was extended down to 100 kc, and construction was completed on a static (conduction) calorimeter and on a power measuring bridge for the range, 0.1 to 100 mw. Final tests were made on the maximum accuracy attainable with the liquid-flow calorimeter which is to be used for frequencies from 0 to 2,500 Mc.

Voltage. High-frequency voltage standards are needed by industry and scientific organizations for all types of voltmeters, voltage sources and generators, modulation meters, wave analyzers, and other electronic equipment.

During the year, much work was done on the development and construction of rf voltmeter calibration consoles for the Calibration Center. One console, housing secondary standards for 5, 10, 30, and 100 Mc for voltages between 0.2 and 300 volts, was almost completed and partially tested with very satisfactory results. In addition, considerable work was done on the consoles covering frequencies from 30 to 100 kc and from 300 to 700 Mc.

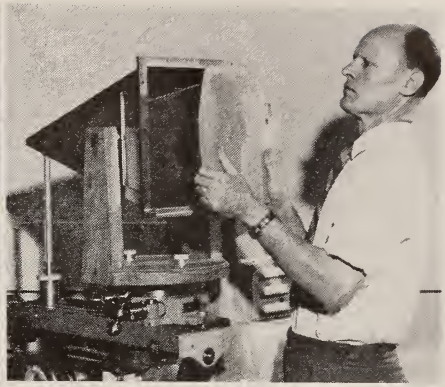
Research and development continued on attenuator-thermoelement (AT) voltmeters. The behavior of capacitive attenuators using electrodes with several different configurations was studied in detail and an expression derived for the capacitance of a conical condenser. The data were also used in developing two models of the AT voltmeter which had much greater voltage ranges, and with improved stability, reproducibility, and ease of operation.

Development also continued on balanced and unbalanced types of rf micropotentiometers. Improvements were made in fabrication techniques.

Dielectric Measurements. The program in dielectric measurements aims to develop and improve standards, equipment, and techniques for measuring the dielectric properties of solids, liquids, and gases over a frequency range extending from low-radiofrequencies to above 100,000 Mc. Materials standardized under this program include insulators, memory materials, capacitor and cable dielectrics, magnetic materials, vacuum tube ceramics, printed circuit boards, and many others of importance to the country's industry. Studies of the dependence of dielectric properties on temperature and other factors also contribute to basic solid-state physics.

In the past year, research was begun on the working out of convenient calculation schemes and tables for computing the dielectric constant of rods of sample materials from the measured effects produced when they are inserted into resonant cavities of several types. Some of these were brought to a useful state of completion; others have given promising preliminary results. Also, a 30-Mc IF pound stabilized oscillator was constructed and put into use.

Magnetic Materials. Magnetic materials are used in nearly every type of electronic system developed for the commercial market as well



Left: **Radiofrequency power-measuring bridge provides hundredfold increase in accuracy over previous instruments of this kind (p. 91).**

Right: **A dielectric lens for use in microwave measurements of the velocity of light is fitted to a horn radiator (p. 94).**

as for military equipment. New and better measuring equipment, techniques, and standards are in constant demand for evaluating new materials as well as for quality control of manufactured materials in order to improve the reliability of electronic equipment. Also, a basic study of the properties and applications of magnetic materials is needed for the synthesis of new materials and to help solve fundamental problems in the rapidly expanding field of solid-state electronics.

During the past year, more exact operating equations were developed for the rf permeameter, a permeameter and associated equipment for measuring parallel reversible permeability were placed in operation, high-current equipment for measuring high-power rf loss was designed and constructed, a half-wave variable-length cavity for initial permeability measurements in the 100- to 300-Mc range was constructed, another cavity for the 300- to 6000-Mc range was designed and partially constructed, an electromagnet for use in investigating properties of magnetic materials was placed in operation; and exact solutions were developed for microwave cylindrical cavity resonators containing a gyromagnetic (magnetized ferrite) sample.

Microwave Spectroscopy of Gases. Work continued on the analysis of data for a revised edition of the circular on molecular microwave spectra tables. Besides providing a compendium of precise spectroscopic and molecular data useful in many branches of science and industry, these tables will make available many secondary and tertiary frequency standards. Analysis of the dielectric and absorption data permits reliable estimates to be made of these characteristics for materials and at temperatures and pressures for which data are not available.

Analysis of most of the existing data on microwave spectra of free atoms and molecules has been completed. Most of the electronic computing-machine operations have been programed for preparing the tables of data for publication. Machines are being used for sorting and printing and

for computing intensities in order to reduce errors in the thousands of computations and transcriptions.

Millimeter Waves. Because of the new phenomena associated with millimeter and submillimeter waves, and their potential applications to practical devices, these extremely short waves have been the object of intensive study by both scientists and engineers. Standards for their measurement are therefore expected to be in early demand. To develop such standards, new paths will have to be explored since conventional microwave techniques become less efficient or fail completely as the wavelength diminishes. For example, the use of quasi-optical techniques at millimeter wavelengths has proved fruitful in wavelength and dielectric measurement. In addition, the shorter microwaves have unique application to standards and measurement in other fundamental areas such as frequency, length, the velocity of light, and the nature of matter.

Thus far, the two main investigations have been: (1) The examination in an absorption spectrometer of a line of oxygen at 5 mm to evaluate its suitability as a possible atomic frequency standard and (2) development of an interferometer at 6 mm for application to measurement of the velocity of light, metrology, and dielectrometry.

The first investigation showed that a frequency control to 6 parts in 10^{10} or better could be obtained. The second investigation is at the stage of careful construction of a precision interferometer after satisfactory experience was gained on a pilot model. An exact theory was developed to describe the diffraction correction to the apparent wavelength indicated by the interferometer.

2.16. Basic Instrumentation

The past year was the seventh during which the Bureau has been engaged in a program of research and development in basic instrumentation supported cooperatively by the Office of Naval Research, the Air Force Office of Scientific Research, the Atomic Energy Commission, and the National Bureau of Standards. As in previous years, the program consisted of three parts: (1) Basic instrumentation research and development, (2) critical surveys of specific areas of instrumentation, and (3) instrumentation reference and consultation. In carrying out this program, the central office coordinates the specialized knowledge and skill of Bureau staff members in a wide range of fields to focus on the solution of instrumentation problems.

This office also endeavors to encourage and stimulate research and development throughout the nation on measurement devices and techniques. To fulfill its responsibility as technical consultant to Government and industry on instrumentation, it maintains active familiarity with technical progress in other laboratories and it cooperates with technical societies in promoting instrumentation progress. Moveover, it cooperates with other Government agencies in arranging conferences and symposia on subjects of special interest or of rapidly developing

importance in the field of instrumentation. These activities often help to define areas of instrumentation in which research and development work needs to be done, either at the Bureau or elsewhere.

The principal emphasis, throughout the program, is on the fundamentals of measurement and control and on development of the science of instrumentation. Preference is shown to those research projects that seem likely to have broad utility in measurement or to extend significantly the range, reliability, or sensitivity of some general class of instruments. Also given primary consideration are theoretical and experimental studies of problems common to many instruments—drift, lag, and unsteadiness, for example—or of the limits of performance inherent in various types of instruments.

One extensive group of problems relates to the handling of signals. Because the output of any sensing element is a signal, such problems can be profitably studied on a very general basis, without regard to particular types of measurement. Areas in which such general studies are encouraged include amplification, loss of information in transmission, analog-to-digital conversion, indication or display, recording, separation of measurement signals from extraneous signals or noise, automatic data correction or reduction, automatic computation, and automatic control.

The research and development activities of the program have been carried out largely through assignment of instrumentation research projects to those NBS laboratories that are best qualified in the fields of science contributing in major part to the problem. The central facility also includes a small laboratory staff for investigation of special problems and a group of specialists in instrumentation literature who are developing and operating a reference and consultation center to aid in the solution of instrumentation problems.

Projects carried on in the basic instrumentation laboratory itself are generally confined to those that call for exploratory studies by a versatile group specializing in instrumentation. Representative examples of these projects are discussed below.

Instrument Reference Service. Both the newness of the field of instrumentation and its rapid growth have posed problems for those scientists in Government and industry who need to have convenient, rapid, and thorough access to instrument information. Two major obstacles stand in their way. The first is the inadequate coverage of instrumentation provided by existing abstracting and indexing services whose main interest is in the information obtained by use of the instrument. The second is the lack of efficient classification systems for instrumentation. The Bureau has therefore established an instrument reference center whose objective is to improve accessibility of instrument information in four ways: (1) by developing improved systems for storage and retrieval of information; (2) by fostering developments elsewhere that will make instrument information more readily available; (3) by surveying specific developments in instrumentation; and (4) by providing consultation services in instrumentation.

Indexing System. The indexing system described in previous reports is in routine operation. Improved card punches have been constructed and are being operated to place a large accumulation of classified and coded instrumentation literature in the special card system. Improved plastic cards have been procured which permit greater reliability and accuracy of punching and greater durability of the valuable file. A large number of consultation inquiries from Government agencies and their contractors have been handled.

Improved Indexing Systems. A number of methods and techniques for improving methods of storing and searching for information generally, and for instrumentation information in particular, have been investigated. One of these is a technique for eliminating one of the steps of the existing system, and for providing a rapid means for modifying a search in the light of material turned up by the search.

Surveys. Another important service of the basic instrumentation program is the preparation of critical surveys of various areas of instrumentation. These are conducted to provide systematic analyses of available methods and devices in terms of their performance and characteristics. While such surveys are of general usefulness, they should be particularly valuable to those charged with planning or conducting research and development on the devices treated or in areas where these devices will be needed.

In the past year a survey of thickness measurement has been prepared for publication as an NBS Circular. A draft of the second part of a survey of recording methods and instruments has been completed. Near completion is a survey of instrumentation for measuring true airspeed and free-air temperature.

Exploratory Investigations. Studies of this class carried on in the basic-instrumentation laboratory included the following: Investigation of the sensitivity to pressure of the resonant frequency of a diaphragm as a means of sensing pressure directly in terms of frequency; investigation of the general characteristics of the Cartesian diver as a measurement principle; investigation of photoconductivity as a frictionless contact in potentiometer-type displacement transducers; and investigation of the reproducibility of electrical contacts as displacement detectors.

3. Calibration, Testing, and Standard Samples

Bureau activities in the fields of calibration, testing, and standard samples are an outgrowth of its custody of the national standards of measurement. However, the demands of modern industry and science for standards, measurement techniques, and precise testing and calibration have outdistanced the Bureau's ability to provide direct services. The Bureau has thus fostered and encouraged the establishment by private enterprise of standardizing laboratories competent at a level of accuracy intermediate between NBS and that of their customers. Whenever prac-

tical, the Bureau has provided standard samples to enable individual scientists to maintain their own standards.

The policy of the Bureau to withdraw from those special areas of calibration and testing which are served adequately by such laboratories was re-emphasized by the Director, speaking on June 11, 1957, at the dedication of the International Telephone and Telegraph Standards Laboratory. The increased availability of private facilities for secondary standardization will enable the Bureau to fulfill its primary functions, among which are the calibration of master instruments and the establishment of new and improved methods of measurement. By working with professional scientific organizations, with specialized standardizing laboratories, and with groups involved in the science of measurement, the Bureau can serve more effectively in spreading the benefit of standards and measurement throughout the economy.

3.1. Assistance in Establishing Standards Laboratories

The demand for increased accuracy by industry has resulted in the establishment of standardizing laboratories by a number of large manufacturing companies and by military organizations. In a number of cases the Bureau was called on for aid in designing laboratories and in selecting equipment. Several senior members of domestic research organizations, as well as visitors from foreign countries, consulted with the Bureau staff in order to acquire such detailed information.

To assist in the establishment of electrical standards laboratories, the Bureau issued a circular suggesting techniques and principles that experience has shown to be useful in such operations. Although it covers explicitly only the field of electrical measurements, many of the principles involved are equally applicable in other kinds of measurement. For the sake of clarity, the measuring instruments and apparatus are divided into five categories; they are: Reference standards, working standards, comparison equipment, interlaboratory standards, and shop instruments and measuring apparatus. The new publication entitled *Suggested Practices for Electrical Standardizing Laboratories*, National Bureau of Standards Circular 578, by Francis B. Silsbee, 9 pages (15 cents), is available at the Government Printing Office, Washington 25, D. C.

3.2. New Calibration Facilities and Equipment

To meet the needs of science, industry, and the Government, the Bureau is constantly developing new calibration facilities which contribute to higher accuracy and new and improved standards. These range from small items of laboratory equipment to installations the size of the new Calibration Center at Boulder.

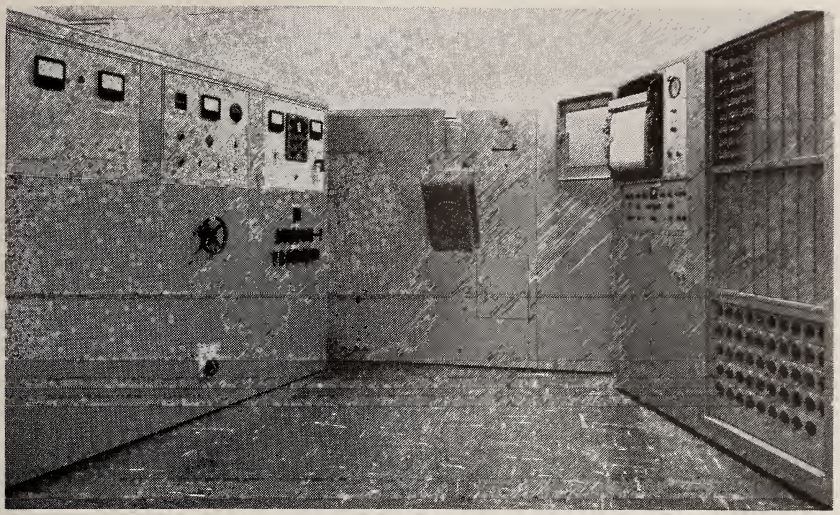
Electronic Calibration Center. At the end of the year, the new 2,700 square foot wing that will house the $2,000,000 Calibration Center of the Boulder Laboratories was practically completed. New and improved

The new 2,700-ft² wing which will house the Electronic Calibration Center of the Boulder Laboratories (p. 97).

equipment was under construction for measuring such quantities as attenuation, power, and impedance at low (zero to about 30 kc), high (30 kc to about 300 Mc), and microwave (above 300 Mc) frequencies. Work within the range from direct current up to 30 kc will be shared with the Bureau's Washington facilities. Calibration equipment for the Center has been designed, ordered, and in part delivered and tested. The electrical standards staff in Washington monitored the construction of special equipment of improved stability and accuracy and participated in the training of personnel in test methods to be used. Laboratory furniture, rf generators, detectors and other items needed for equipping the calibration facility are likewise of highest quality. During the year a large part of the radio standards staff was engaged in preparing for the Center, either in the design, procurement, and construction of equipment, or in the development of new and more accurate measurement techniques.

Mobile Cement Testing Laboratory. A new laboratory trailer, completely equipped for the physical testing of Portland cement, began operation at Duluth, Minnesota, during the summer construction season. This mobile facility augments the permanent testing laboratories maintained by the Bureau in Allentown, Denver, San Francisco, Seattle and Washington, D. C., for conducting acceptance tests on cement purchased by the Federal Government. The trailer is equipped with a compression testing machine of 75,000-lb capacity, a high-pressure autoclave, a controlled temperature moist-storage cabinet, and other necessary equipment. At Duluth, the testing operation, which largely concerned construction at the Grand Forks Air Force Base in North Dakota, involved approximately 500,000 barrels of cement. The convenience of a laboratory in the vicinity of the construction work offers distinct advantages and often avoids disruptive delays. While chemical samples weighing a few grams can be readily transported by air to fixed laboratory installations, 10-lb physical samples present quite a different problem.

Resistance Thermometry. The resistance thermometry laboratory, which maintains the temperature scale from ten degrees above absolute



One of three high-speed photoelectric spectrometers recently installed to provide extremely rapid analysis of alloys. The spectrometers will be used to study the homogeneity of alloys designed for distribution to science and industry as certified standard samples (p. 97).

zero to the melting point of antimony (630.5° C), has been relocated and modernized. To more effectively meet the growing demands of science and industry, several new pieces of equipment have been designed and built to improve the accuracy and reduce the cost of calibration service. These include an automatically controlled low-temperature cryostat with means for realizing fixed points in the low-temperature region, such as the normal boiling point of hydrogen, and a manostat for controlling the pressure of the fixed point baths (including the steam and sulfur points) to within 1 micron at approximately 1 atmosphere. Much of the existing calibration equipment has also undergone modifications, such as provisions for automatic data read-out.

High-Speed Photoelectric Spectrometers. In connection with a 3-year program for the preparation of 150 new spectrometric standard samples, three high-speed photoelectric spectrometers for use in studying the homogeneity of alloys were designed and installed. Two of the spectrometers, for optical spectra, are for analysis of a variety of normal and complex alloys including cast irons, steels, titanium alloys, high-temperature alloys, and alloys of copper, lead, and other common metals. The third spectrometer provides for the analysis by X-ray spectra of alloys of iron, tungsten, nickel, cobalt, titanium, molybdenum, and chromium. The spectrometers permit high-speed precise analyses of standard-sample materials to check their uniformity and reliability for the calibration of similar instruments by industrial and Government laboratories.

3.3. Services Discontinued

The decisions to discontinue the distribution of certain standard samples now available from private enterprise and to discontinue the calibration of viscometers reflects the Bureau's current policy. More reliable calibration of these instruments is now obtained under conditions of actual use, by reference to standard viscosity samples provided by the Bureau. Fewer than 60 viscometers were calibrated during the past year, and effective January 1, 1958, the service will no longer be offered. The testing of watches and other timepieces has also been discontinued, for the Bureau radio stations WWV and WWVH provide a much more convenient and reliable means of making standards of time and frequency available for practical use.

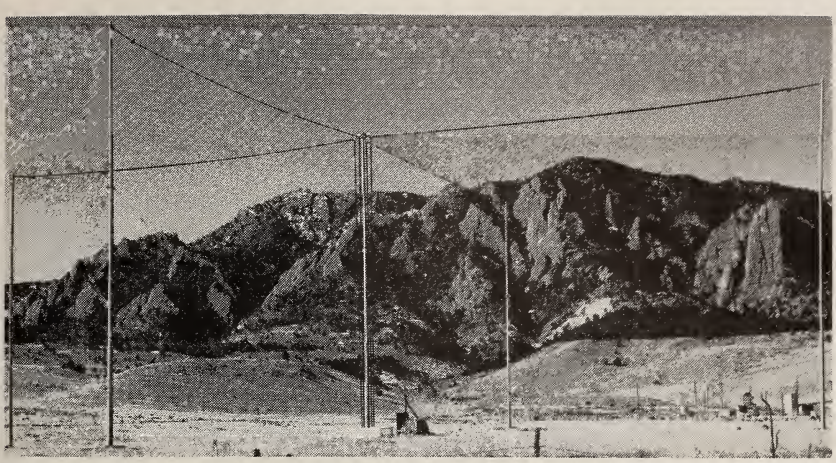
In May 1957, the Bureau discontinued the distribution of the following radioactivity standard samples of short-lived radioisotopes: Phosphorus-32, iodine-131, gold-198, sodium-24, and potassium-42. Standardized samples of these nuclides, now available from the Nuclear-Chicago Corporation, will be derived from comparisons made with the primary standards of the Bureau. This firm, however, has accepted full responsibility for the standardization of the samples that it distributes. The Bureau will continue to maintain the primary disintegration-rate standards of these nuclides, with which commercially available secondary standards may be compared.

3.4. Services to the Public and Government

An important step in spreading the benefits of standards and measurement throughout the Nation is the critical calibration of working standards of industrial and scientific laboratories against the national standards maintained at the Bureau. Testing, on the other hand, is almost entirely confined to request from Federal agencies, usually in connection with quantity purchase of materials for Government use. In addition, small numbers of tests are conducted on a very wide variety of items to supplement the testing services of other Government laboratories.

Calibration and testing services showed an increase over last year and totaled 149,058 items and a dollar fee value of $1,517,187.14. For example, the volume of calibration of electrical standards and measuring instruments has increased about 50 percent over the 1956 figure, reflecting the tendency to use electrical methods and instruments to measure nonelectrical quantities as well as the establishment throughout the Nation of an ever-increasing number of electrical standardizing laboratories. A summary of these services by area of activity to the public and Government is given in the accompanying table.

Frequency and time standards are unique among the physical and electrical standards in that they may be made widely available by means of radio transmissions. To make the United States standards readily available on a worldwide basis, six standard carrier frequencies modulated by standard audio frequencies and time intervals are broadcast con-



Five-pole antenna used in experimental 60-kc standard frequency broadcasts (p. 101). Because this frequency remains stable even when ionospheric variations occur, the experimental broadcast makes possible frequency measurements to 1 part in 1 billion throughout the continental United States.

tinuously from station WWV, Beltsville, Maryland, and three standard carrier frequencies, with modulation, from station WWVH, Maui, T. H. In addition, the stations distribute radio propagation forecasts for the North Atlantic and North Pacific radio circuits. The signals are relied upon by many individuals and agencies such as commercial airlines and shipping lines; by scientific, commercial, and governmental organizations; and by the military agencies. Also, they are of importance to all radio broadcasting activities, including communications, navigation, television, radar, and guided missiles.

An experimental standard-frequency broadcast on 60 kc was begun in July 1956 at the Boulder Laboratories. Because this frequency and lower ones are not as seriously affected by ionospheric layer variations as are the high frequencies, this service makes possible frequency measurements to a precision of at least 1 part in 10^9 throughout the continental United States.

Testing services for Government purchase cover a wide variety of items as reflected in the table on page 102. Typical of these are electric lamps, cement, and other building materials. For example, lamps, under purchase contracts between the Government (Federal Supply Service) and the suppliers, must meet compliance specifications. During the past year, samples inspected represented over 4,400,000 lamps, of which approximately 8 percent were rejected on initial inspection at the factories of the suppliers. Lamps of current suppliers started on life test totaled 4,611, and those rejected represented approximately 5.1 percent of those accepted on initial inspection. Some 6,000 cement samples were tested representing approximately 11-million barrels of cement. In this area the number of tests necessary to obtain quality control has been considerably reduced by the utilization of a new statistical testing procedure.

TABLE 1. *Testing and calibration*

Areas of Bureau activities	Representative items	Public		Government		Totals	
		No. of items	Value	No. of items	Value	No. of items	Value
Electricity and Electronics	Electrical instruments, standard cells, resistance-reactance standards.	5,555	$54,204.00	1,810	$20,920.60	7,365	$75,124.60
Optics and Metrology	Light and color standards, photographic lenses, gage blocks and other length standards, lamps, refractive indices.	25,459	81,600.10	7,817	73,501.00	33,276	155,101.10
Heat	Thermometers and thermocouples, fuels, viscometers, lubricants.	9,376	72,335.85	4,347	20,909.15	13,723	93,245.00
Atomic and Radiation Physics	Radiometric instruments, blood samples, dosimetry standards, radium and radon analysis, radioactive standards, wave-length sources.	572	11,958.77	894	28,000.39	1,466	39,959.16
Chemistry	Reagent chemicals, chemical analyses	9,365	37,989.50	7,562	28,733.75	16,927	66,723.25
Mechanics	Acoustic instruments, proving rings, load cells, dynamometers, pressure standards, track scales, humidity-mass-capacity standards, miscellaneous mechanical devices.	29,846	132,674.16	3,507	65,939.30	33,353	198,613.46
Organic and Fibrous Materials	Paper, textiles, rubber, leather, plastics materials and products.	264	18,610.75	5,573	43,062.35	5,837	61,673.10
Metallurgy	Metals and alloys	2	317.00	45	14,108.00	47	14,425.00
Mineral Products	Cement, concrete aggregates, ceramic materials	9	470.15	34,472	760,790.86	34,481	761,261.01
Building Technology	Building materials, elevators, air filters, fire extinguishers, heating and air-conditioning units.	3	250.00	1,914	35,126.46	1,917	35,376.46
Radio	Electronic instruments, radio instruments and standards	447	7,058.00	219	7,127.00	666	14,185.00
Totals		80,898	417,468.28	68,160	1,098,218.86	149,058	1,515,687.14

In the area of building materials much of the testing contributes to the formulation of improved criteria for selection of materials and equipment for specific uses or for improved test methods and standards. Assistance to Government in this area also included a study, at the request of the Architect of the Capitol, of the 150-year-old exterior sandstone in the original portion of the United States Capitol. Nine samples, cored from the walls of the building, were tested for such properties as compressive and flexural strength, hardness, toughness, specific gravity, porosity, and elasticity. The findings of this study suggested alternate plans for renovation. Since the structure is essentially sound, one-half inch of spoiled stone might be removed by tooling, and the new surface preserved by periodic repainting. A preferable long-term solution would be to reface the old walls with a material such as marble.

3.5. Standard Samples Program

The several new standard samples developed during the year were the first to be established under Public Law 940, which authorized the Bureau to finance this activity from service fees. These samples, bringing the total of standard samples now available to science and industry to 580, include two metal standards, two rubber samples, and an extension of *p*H standards. In addition, a large number of samples were under development to meet pressing needs in industry. This was especially reflected in the initiation of a 3-year program for the preparation of 150 new spectrometric standards of which 55 are nearing completion. To carry out this program, 3 high-speed photoelectric spectrometers were installed (see page 99). During the year, approximately 38,827 standard samples, having a fee value of $188,221, were issued by the Bureau. A summary of the standard samples program by area of activity is given in the accompanying table.

The Bureau *p*H standardization program has resulted in the establishment of six primary standards, specifically for the accurate adjustment of electrometric *p*H equipment over the wide *p*H range 1.68 to 12.45 at 25° C. The assignment of *p*H values is based on the electromotive force of cells making use of the hydrogen electrode, the primary reference standard for all hydrogen ion determinations. In many instances, however, where high accuracy is not required, *p*H is determined by matching the shade of color produced by a color indicator in the test solution with that produced by the same indicator in solutions of known *p*H. For this purpose, the six primary standards are insufficient. The *p*H of a series of secondary standards has therefore been determined with reference to the primary standards. These solutions cover the *p*H range 1.0 to 13.0 in intervals of 0.1 *p*H unit.

Two new standards of certified composition were prepared, a leaded-tin bronze, and a titanium-base alloy. Twelve renewals of exhausted standards were also prepared. These included 7 steels, 2 cast irons, 1 tin-base alloy, 1 manganese ore, and 1 melting-point zinc. At the request

TABLE 2. *Standard Samples*

Areas of activities	Description of samples	Public		Government				Totals	
				Federal		State			
		No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value
Optics and Metrology	Resolution test charts	1,999	$399.80	377	$67.40	25	$5.00	2,301	$472.20
Heat	Viscosity oils	820	13,243.00	59	842.50	63	919.50	942	15,005.00
Atomic and Radiation Physics	Radioactive samples	421	8,325.00	215	4,247.20	178	3,319.80	814	15,892.00
	Meggers lamps	2	300.00	6	900.00	3	450.00	11	1,650.00
Chemistry	Paint pigments	23	69.00	2	6.00	1	3.00	26	78.00
	Sucrose and dextrose	293	979.25	29	96.25	38	128.50	360	1,204.00
	Composition	21,011	81,903.20	1,082	3,907.75	525	1,834.00	22,618	87,644.95
	Spectrographic	3,536	20,511.00	241	1,506.00	33	202.00	3,810	22,219.00
	Hydrocarbon	328	9,472.00	47	1,396.00	45	1,398.00	420	12,266.00
Organic and Fibrous Materials	Standard fading samples	477	4,835.00	18	146.00	9	96.00	504	5,077.00
	Rubber	4,701	20,603.70	42	220.50	1	2.50	4,744	20,826.70
Mineral Products	Cement	2,070	5,175.00	10	25.00	84	210.00	2,164	5,410.00
Building Technology	Limestone slabs	45	405.00	8	72.00	------	--------	53	477.00
Totals		35,726	166,220.95	2,096	13,432.60	1,005	8,568.30	38,827	188,221.85

of industry, work is in progress to establish new standard samples of lithium ores, alumina-silica refractories, and additional titanium-base alloys. A survey of a number of metallurgists also established the need of metallurgical standards which would aid industrial laboratories to determine accurately the gas content of certain metals. Accordingly, the Bureau has undertaken a program to develop eight steels as standards.

The first rubber samples to be issued as standard materials were added to the list of standard samples of rubber compounding ingredients during 1957, making a total of 15 samples. Two of the existing standard samples were exhausted and replenished during the year. These rubber samples are styrene-butadiene synthetic rubber, types 1,000 and 1,500. The sample of type 1,500 synthetic rubber, which was issued in the amount of 26,000 pounds, was sponsored by ASTM Committee D–11 on Rubber and Rubberlike Materials.

The sale of standard samples of paper and standard booklets for calibration or carbon-arc fading lamps, for use in fading and weathering tests, continued to increase. Two mill runs of paper totaling approximately 550 pounds were made, standardized, packaged, and printed during the year.

At present, the Bureau accepts only new sieves for calibration. During the year, however, a project was initiated for the preparation of standard samples of calibrated glass beads suitably graded for use in calibrating sieves. With these standard beads it will be possible for industry to accurately calibrate any of its sieves on plant premises, using the same methods as those by which industrial materials are tested.

4. Cooperative Activities

An important function of the Bureau—cooperative and consultative activities for Government, science, and industry—arises from the diversity of the Bureau's program, facilities, and staff in all areas of the physical sciences. These activities range from standardization and research projects in cooperation with other groups to active participation in scientific and technical society programs.

Finished documents on codes and specifications are usually promulgated by the sponsoring society or agency; the Bureau contributes by providing methods of test, data on properties of materials, and standards of measurement, which are fundamental to all standardization work. Cooperation of this type permits Bureau personnel to keep abreast of technical and scientific developments elsewhere, and provides an opportunity to reconcile differences existing between the methods of measurement and requirements in Government specifications and standards, and those used in industry.

The Bureau's participation in national and international professional societies and standardization groups is implemented by membership on committees and subcommittees. During the year, about 1,550 member-

ships from about 180 technical societies were held by members of the staff, in many instances as officers of the committees.

Cooperative activities were extensive with such groups as the American Society for Testing Materials, American Standards Association, American Chemical Society, American Physical Society, American Institute of Electrical Engineers, American Society of Mechanical Engineers, Institute of Radio Engineers, Society of Automotive Engineers, Society of the Plastics Industry, International Organization for Standardization, International Association of Dental Research, American Association for the Advancement of Science, and Illuminating Engineering Society.

4.1. Federal Specifications

Participation in the preparation of uniform specifications and test methods for use in procurement by the Federal Government represents an important area of the Bureau's cooperative activities with other agencies of the Government and with industry.

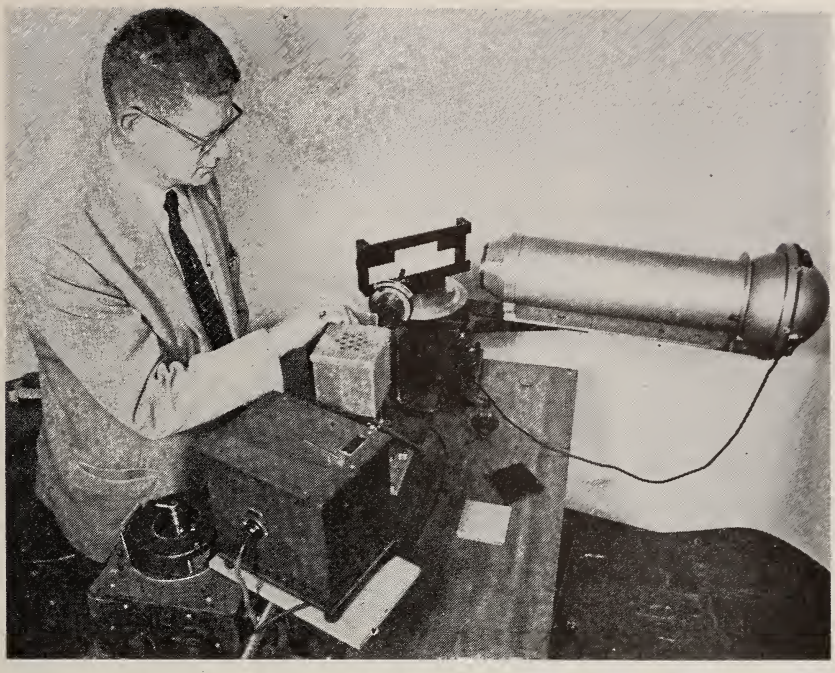
The Bureau has accepted the responsibility for the preparation and maintenance of 215 Federal Specifications covering a wide range of materials and products. In developing and maintaining these specifications, the Bureau frequently utilizes information obtained from its investigations of the properties of materials, and from its broad research and development programs. Use is also made of knowledge obtained through cooperation with scientific and technical groups, and industry organizations, which sometimes permits the Federal adoption in whole or in part of specifications already in use in industry. The Government is thus saved the cost of developing the specifications; industry benefits through familiarity with the materials defined by them. Federal Specifications are frequently used by State and municipal governments, and by large commercial purchasers.

At the request of the General Services Administration and other agencies, the Bureau reviewed approximately 500 proposed specifications to comment on technical adequacy, and the suitability of test methods. Most of the suggested changes concerned proper sampling and test procedures.

4.2. Methods of Test

The development of test methods is one of the statutory functions of the Bureau. For Federal Specifications, the Bureau attempts to develop methods that will be applicable to groups or classes of products or materials rather than methods covering a single item.

The Bureau has accepted responsibility for the development and maintenance of 12 of the 14 Federal Test Method Standards, covering approximately 1,200 methods for rubber, textiles, paper, leather, nontextile floor coverings, adhesives, plastics, detergents, paint, cement, wire and cable, and laboratory glassware. Several of these standards contain sampling plans and definitions that are in common use in industry. Complete



Studying the gloss of clear finishes on wood. The Bureau developed an improved method for measuring gloss of wood finishes which has recently been adopted by the American Society for Testing Materials as a tentative standard (p. 108).

revisions of the standards for laboratory glassware, cements, and paint, involving approximately 300 methods, were prepared during the year. Continuous revision of old methods and the development of new ones as well as periodic complete revision of a standard are necessary to keep abreast of new developments in this area.

4.3. Industry Specifications

If the Federal Government is to purchase satisfactory materials and products at a reasonable price, it is necessary that its purchase specifications be coordinated with those of industry and that full advantage be taken of new developments and improved manufacturing processes. The Bureau is in a position to make an important contribution in this area by its active participation in the work of technical societies, industrial associations, and standardization groups.

The following examples are typical of such activities. In cooperation with ASTM Committee D–20, methods were developed for the simulated weathering of plastics, using a fluorescent sunlamp, and for measuring the water absorption and tensile properties of plastic films. At the request of ASTM Committee D–20 on Plastics, proposed methods for measuring the surface flammability and ignition temperatures of plastics were prepared and submitted to the Committee. Both methods are based on research done at the Bureau. Proposed ASTM specifications for polyvinyl

acetate resin emulsion adhesives and general purpose adhesives were drafted for ASTM Committee D–14 on Adhesives. A revision of the ASTM method for measuring thickness of solid electrical insulation was prepared for ASTM Committee D–9 on Electrical Insulation. ASTM Committee D–1 was aided in the revision of methods of sampling and analysis of lac resins. The two-parameter method of test for gloss, developed at the Bureau, was adopted by ASTM Committee D–1 as a tentative standard. Extensive cooperation was given ASTM Committee E–3 on the preparation of the sixth edition of "Chemical Analysis of Metals" comprising 627 pages. A specification for acoustical adhesives based on an evaluation program at the Bureau was adopted by ASTM Committee D–14 on Adhesives.

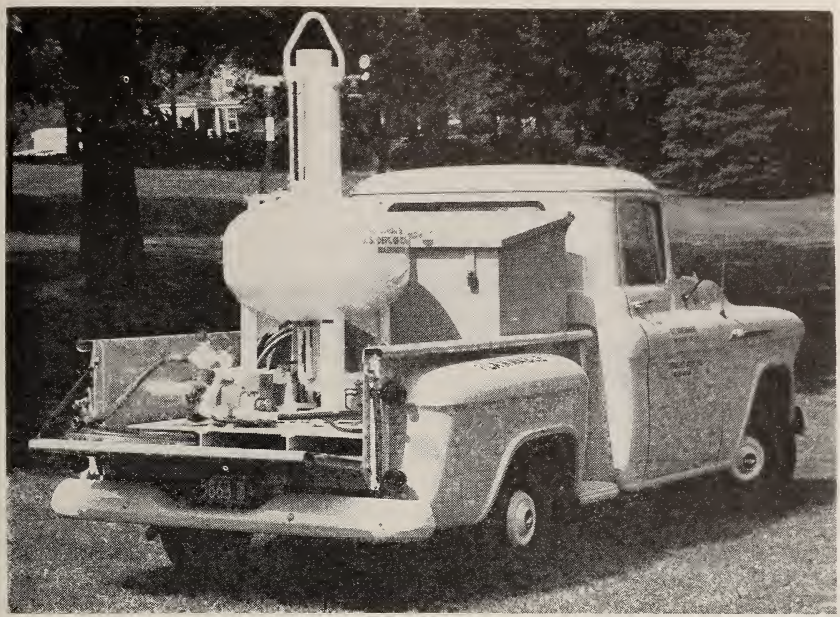
The Bureau is cooperating with the International Committee for Cellulose Analysis, American Chemical Society, American Society for Testing Materials, and the Technical Association of the Pulp and Paper Industry, in an endeavor to standardize methods for determining the functional groups in cellulose and cellulose derivatives. This standardization is essential because these methods are basic tools for determining the properties and reactions of cellulosic materials. It will also help research workers throughout the world to better understand the significance of work published by others in the field.

Extensive aid was given the Illuminating Engineering Society in the revision of the IES Lighting Handbook and in the work of its Committees on Aviation Lighting, Motor Vehicle Lighting, and Nomenclature. "Tips to the Motorist", which lists safety steps in night driving, was issued as part of the "Back the Attack on Traffic Accidents" campaign by the IES Motor Vehicle Lighting Committee under direction of its NBS chairman. A Guide to the Photometry of Searchlights was also prepared.

Assistance was given the Scientific Committee of the Waxes and Floor Finishes Division of the Chemical Specialties Manufacturers Association in their work on floor wax evaluation. In cooperation with the Office of Technical Services, U. S. Department of Commerce, the industry committees of the Society of the Plastics Industry were assisted in the development of nine commercial standards covering such items as garden hose, structural panels, plastic tubes, and plastic pipe. A specification for hydraulic actuators was prepared for the AIEE Feed Back Controls Committee.

4.4. Cooperative Research With Industry

The Bureau's Research Associate Plan, a cooperative program with American industry, has resulted in many significant developments in science and technology. Under this plan, technical, industrial, and commercial organizations can support work at the Bureau on projects that are of special interest to them, yet are of sufficient general interest to justify use of Government facilities. These projects must also be



A lack of uniformity in devices measuring liquefied petroleum gas led the States to request the Bureau to develop equipment for testing such meters. This equipment, which allows quick and easy "proving" of the measuring devices, will be used by meter manufacturers, the liquefied-petroleum-gas industry, and weights and measures enforcement officials (p. 111).

important from the standpoint of the Nation's sum total of technological knowledge.

Since 1920, when the Research Associate Plan was established, over 180 organizations and individuals have supported cooperative research at the Bureau. At the present time, 10 groups are supporting research associates at NBS, in the following areas:

Sponsor	*Field of Activity*
American Dental Association	Dental research and testing.
American Electroplaters Society	Research on electroplated coatings.
American Society for Testing Materials	Cement reference laboratory.
Asphalt Roofing Industry Bureau	Asphalt roofing research.
Bone Char Research, Inc	Research on adsorbents for sugar refining.
Calcium Chloride Association	Hydration of portland cement.
Corrosion Research Council	Corrosion of metals.
National Research Council	Masonry research.
Porcelain Enamel Institute	Test methods for porcelain enamels.
Portland Cement Association	Cement research.
Joint Committee of Chemical Analysis by X-ray Diffraction Methods. (ASTM & Am. Crystallographic Assoc.).	Standard X-ray diffraction powder patterns.

The results of the projects supported by the Research Associate Plan become a part of the public domain and are published by the Bureau. Whereas many projects are specific in nature and of short duration,

others, such as those sponsored by the Portland Cement Association and the American Dental Association, are directed toward fundamental research and have been active for a number of years. Accomplishments of the program during 1957 are reported in section 2.

Another important and similar area of cooperation between the Bureau and industry is the program authorized in 1950 by Public Law 619 under which the Bureau is authorized to accept funds for the purpose of furthering its work. This arrangement permits individuals as well as technical, industrial, and commercial organizations to support work at the Bureau when the results are expected to be of value to the general public.

During the past year, 17 projects were supported by gifts from 23 organizations as follows:

Donor	*Field of Activity*
American Dental Trade Association	Standards for color of dental equipment.
American Iron & Steel Institute	Standard samples of ferrous metals, steel research.
American Iron & Steel Institute	Design stresses for reinforced concrete.
Dearborn Gage Company	Precision gage block program.
DoAll Company	Precision gage block program.
Edward Orton Jr., Ceramic Foundation	Research in clays.
E. I. DuPont de Nemours & Co., Inc	Precision gage block program.
Georgetown University	Physiological research.
Greenfield Tap and Die Corp	Precision gage block program.
Hughes Aircraft Company	Precision gage block program.
International Business Machines	Precision gage block program.
International Nickel Company	Revision of Circular, "Nickel and its Alloys," research on low alloy steels.
National Electrical Manufacturers Association	Safety devices in refrigerators.
National Lime Association	Hydration of lime.
Pratt & Whitney Company	Precision gage block program.
Radio-TV Electrical Manufacturers Association.	Luminous standards of color phosphors.
Taft-Peirce Foundation	Precision gage block program.
The Sheffeld Corporation	Precision gage block program.
The Van Keuren Company	Precision gage block program.
Timken Roller Bearing Co	Precision gage block program.
United Engineering Trustees, Inc	Stress corrosion, research on metal single crystals.
Welding Research Council	Stress-corrosion cracking of stainless steel.
Anonymous	Ether peroxides.
Anonymous	Phenomena of crystallization.

4.5. Weights and Measures

The Congress has left to the individual States the responsibilities of regulating commercial weighing and measuring devices, and of controlling commercial transactions involving quantity. The Bureau cooperates with the States in this endeavor through its Office of Weights and Meas-

ures. Commerce, business, and consumers are becoming increasingly aware of the importance of adequate weights and measures administration. This, plus the rapid introduction of new instruments and techniques in the field, brings greater demands upon the Bureau each year for assistance and advice.

The Office of Weights and Measures plans and conducts several integrated programs of assistance to States and local jurisdictions, as well as to business and industry. The range of consultative services is broad, embracing the drafting of new legislation; development of regulations, including technical specifications and tolerances for devices; guidance in administrative procedures; design of testing equipment; and preparation and distribution of recommended testing methods. Also included is the physical adjustment of State reference weights and measures standards.

During 1957 the Bureau continued its on-the-job training of technical personnel from the various States. Training schools and work shops were planned and conducted, involving classroom-type of instruction, and physical demonstrations of equipment.

An intensive survey was conducted, at the request of the State of Arkansas, on weighing and measuring devices and practices. The findings of this survey were submitted to the Arkansas Legislative Council in the form of a report, supplemented by a proposed weights and measures bill. Special surveys were made in three States on vehicle-tank and loading-rack meters.

Metering Liquefied Petroleum Gas. Because of the tremendous rise in the use of liquefied petroleum gas, a system of sale by liquid measure through positive displacement meters has evolved. At the request of the States, the Bureau undertook the development of special equipment for testing such liquid meters and thus made available to the meter manufacturers, the liquefied-petroleum-gas industry, and weights and measures enforcement officials, equipment that makes possible quick and easy "proving" of the measuring devices for accuracy.

The 42d National Conference. One of the most effective movements toward nationwide uniformity in weights and measures administration is the National Conference on Weights and Measures, sponsored by NBS since its inception in 1905. The 42d Conference, held in Washington in June of 1957, was attended by almost 450 delegates, representing 38 States, Alaska, the District of Columbia, and Puerto Rico, as well as consumer groups and all phases of business and industry associated directly with weights and measures supervision. The Conference concerns itself with the technology of weights and measures supervision, and adopts and recommends to the States model laws and regulations.

The Conference adopted for the first time a "Statement of Organization and Procedure" (see appendix for full text of Statement, p. 124), that was developed and recommended by a special-study committee appointed by the President (the Director, NBS) covering: (1) Objectives, (2) relationship with the National Bureau of Standards, (3) constituent membership, (4) officers, (5) committees, (6) duties of officers,

(7) duties and fields of operation of committees, (8) voting, (9) procedures, (10) changes in organization and procedure, and (11) parliamentary procedure.

The production of audiovisual aids in the form of motion pictures is one phase of the education program conducted by the Conference, and the Office of Weights and Measures. A motion picture, "Assignment—Weights and Measures", is near completion. This 18-min., 16-mm, color and sound film portrays the importance of weights and measures supervision to the average family.

4.6. Free-Radicals Research Program

In October 1956, the Bureau undertook a 3-year program of basic research on free radicals. The object of the program is to increase fundamental knowledge on the formation, properties, and storage of these highly reactive molecular fragments. The work is receiving support from the Department of Defense through the Office of Ordnance Research, Department of the Army.

To encourage broad dissemination of the information obtained in the program, and to minimize interference with other established projects at the Bureau, participating scientists have been drawn largely from other institutions. Approximately half of the technical staff for the free-radicals research program is on loan from industrial-research laboratories; others have come from universities and various Government agencies. It is expected that the work of this central research group will be continued and expanded in many industrial laboratories after termination of the present program.

A technical-data center has been set up so that free-radical research at other laboratories, both in the United States and abroad, may be closely followed. Other activities serving to knit together the various research projects making up the program include weekly seminars, and a general conference planned for September 1957.

The program is now firmly established and a number of projects are already under way. These include, among others, spectroscopic investigations of condensates from electric discharges; X-ray and electron-diffraction studies of the structure of solids containing free radicals; methods of preparing pure free radicals by photolysis and gamma irradiation; and theoretical calculations of recombination rates, heats of reaction, and other properties.

4.7. Educational Program

The broad educational program at the Bureau provides an opportunity for the scientific staff to further their education and increase their opportunities to take on added responsibilities.

The NBS Graduate School Program is divided into courses classed as NBS out-of-hours, NBS in-hours, and NBS-university sponsored out-of-hours courses. The program is flexible to meet the varied and changing

needs of the research staff. Research workers from other Government agencies may enroll in the NBS classes if the knowledge gained will assist them in their official duties. Since the establishment of the educational program in 1908, over 13,000 registrations have been recorded, and more than 170 graduate degrees have been awarded by 35 different universities, partly on the basis of credits obtained, or the thesis work carried on, under the Bureau program. During the past year there were 1,094 registrations in 43 courses offered at the Washington and Boulder laboratories.

A summer Junior Scientist-Engineer program is open to the especially well-qualified scientific student with possibilities for a future career at the Bureau. It consists of orientations, training assignments, and discussions with advisors from the technical divisions.

Postdoctoral Resident Research Associateships recommended by the National Academy of Sciences-National Research Council are tenable at the National Bureau of Standards, 1 of 2 laboratories in the United States which provide this opportunity. Young scientists at the Ph. D. level participate in basic research in the physical and mathematical sciences. This is the third year of the program and the Bureau has 8 associates, 3 in chemistry, 3 in physics, and 2 in mathematics.

The educational program also includes a series of seminars, colloquia, and lectures. The seminars and colloquia are of a specialized nature and are devoted to detailed discussions. The weekly Scientific Staff Meetings are of a more general nature. They are open to all members of the professional staff at the Bureau and are also regularly attended by scientific personnel from neighboring laboratories. Designed to keep Bureau personnel abreast of current developments in the various fields, these lectures are given by both members of our own staff, and scientists from universities and other laboratories in the United States and abroad. Lectures by members of the Bureau staff include a yearly report to the staff by the Director, a periodic review of the work of the divisions by their division chiefs with an accompanying division open house to increase the interdivision exchange of ideas and contacts, lectures on current research of broad general interest to other members of the staff, reports by staff members on international meetings, and reports from fellowship scientists on research work at other institutions in this country and abroad. About two-thirds of the program is devoted to lectures by guest scientists.

4.8. International Cooperation

The Bureau contributes to the establishment of internationally recognized standards and practices through cooperation with international standardization and professional groups. This cooperation is very important to American trade, industry, technology, and science.

A member of the NBS staff presided at the Sixth Meeting of the Technical Committee on Plastics of the International Organization for Standardization (ISO) held in The Hague. Statistical guidance in planning interlaboratory tests on shrinkage in laundering of textiles, and assistance

in interpreting the results of the tests were furnished to the Technical Committee on Textiles. Comments of the American Group on 3 proposed ISO recommendations of the Technical Committee of Lac were assembled and submitted to the American Standards Association for transmittal to the Secretariat. The Bureau, through the chairman and members of the American Group of the Technical Committee on Rubber, has assisted in the development of six ISO Recommendations on Rubber which have been approved by the ISO Council and are available as standards to those countries desiring to use them.

A member of the staff reported the latest measurement made on the absolute determination of the ampere to the Consultative Committee on Electricity of the International Committee on Weights and Measures. Scientists from the Bureau, serving as Secretary of the U. S. National Committee of the International Commission on Illumination, Chairman of the International Working Committee on Colorimetry, and Chairman of the U. S. Technical Committees on Colors of Signal Lights and Photopic and Scotopic Vision, are assisting in preparations for an international conference to be held in Brussels in 1959. Members of the staff serve the International Union of Pure and Applied Chemistry as President of the Section of Inorganic Chemistry; President of the Commission of Atomic Weights; President of the Commission of Electrochemical Data; and Secretary of the Plastics and High Polymer Division. Studies on the prediction of atmospheric noise and its variation with location, frequency, and time were presented to the Eighth Plenary Assembly of the Consultative Committee on International Radio by members of the staff. As a part of the program of the International Cooperation Administration (Point 4 Activity) a member of the Bureau staff was sent to Ethiopia. He surveyed conditions there and advised the U. S. Operations Mission on the desirable size, functions and organization of a proposed National Bureau of Standards of Ethiopia.

The Bureau has always welcomed the cooperation of foreign scientists and students in its research and standardization programs. Under the various international fellowships and Point 4 programs, foreign nationals have worked with Bureau scientists on problems in the physical sciences of mutual interest to their countries as well as to the United States. During 1957 the Bureau received more than 1,000 foreign trainees, visitors, guest workers, and leaders seeking information or training in their fields of specialization.

4.9. Other Cooperative Activities

Safety Codes and Building Technology. Close liaison is maintained with the Federal Construction Council of the National Academy of Sciences, and members of the Bureau staff served on a number of task committees established to study Government building practices, and to make recommendations for improvement. Extensive cooperative work was done with model code-writing bodies such as the Building Officials Conference of

America, the Southern Building Code Congress, and the International Conference of Building Officials.

During the year, revision of the Code for Protection Against Lightning was completed and the draft submitted to the sponsors for approval. A final draft of the code for the Protection of Head, Eye, and Respiratory Organs was completed. Satisfactory progress is being made on the revision of the National Electrical Safety Code and on the Elevator Inspectors' Manual. The Bureau is cooperating actively with a number of technical and scientific organizations in the preparation of building and safety standards and model codes. Work was done on Minimum Requirements for Building Codes, Code for Parking Garages, Punch Press Code, Standards for Reinforced Masonry, Over-head Cableways for Passenger Transportation, and Interpretations of the National Electrical Code.

During the year, 4,159 cities, each with a population of 2,500 or over, were surveyed as to the status of their building codes. The survey showed that codes are being revised and brought up to date more frequently now than was previously done. The use of model codes to which the Bureau made substantial contributions is very widespread.

Other Government agencies depend upon the Bureau to assist them in solving their technical problems by supplying accurate information on building materials and structures with regard to strength, fire resistance and durability, and heating and air-conditioning.

Dental Materials. The dental research program at the Bureau is carried on in cooperation with the American Dental Association and the Dental Corps of the Armed Services and the Veterans Administration. The objective of the greater part of the work is to provide information on the properties of dental materials and equipment, as a guide to these agencies in the purchase and use of dental items.

The Armed Services and Veterans Administration were advised on the properties of the newer synthetic-rubber impression materials, the physical properties of human enamel and dentin, the physical properties of gallium-copper-tin alloys, and the use of high-speed methods of cutting teeth.

The Bureau aided the USAF in setting up the Panoramic X-ray for clinical evaluation, demonstrating that it has great value for surveying and recording the oral condition of military inductees. This device, developed at the Bureau, has many other uses.

Assistance was given to the Armed Services Dental Corps in training dental officers in research methods and the use of dental materials. The Armed Services Dental Corps assign officers to the Bureau for training and send special postgraduate groups for lectures and demonstrations. Staff members of the Bureau lectured on special subjects as part of the regular curriculum of the Navy and Army dental schools. Lectures and clinics were given at several other dental schools, and at meetings of professional and research dental groups.

Applied Mathematics and Data Processing. The Bureau maintains one of the principal facilities to which other Federal agencies turn for assistance in the solution of their mathematical problems. One important aspect of this work lies in the fact that coding for electronic computations is done not only for the Bureau's own machines, SEAC, and the IBM 704, but also for NORC, UNIVAC, and ERA 1103, at the request of outside agencies.

Among such problems studied for other Government agencies were: Solution of a set of partial differential equations arising in a reactor design problem; angular distributions and polarization effects in nuclear scattering; molecular-structure calculations; award of procurement contracts by linear programing; computation of wave functions by Hartree method; charged particle trajectories in magnetic field of the earth; multiple scattering in cross-section measurements; radar scanning problem; and a study of microwave properties of ferrites.

Methods for sampling current production of ship steel for the purpose of studying the variation of nine physical and chemical properties have been worked out for the Bureau of Ships—NRC Ship Steel Committee. The sampling procedure is so arranged as to concentrate attention on the most important sources of variation so that effort is not wasted on factors previously shown to be relatively unimportant.

Services were also rendered to the U. S. Geological Survey on developing methods for the analysis of orientation data and on correlation analysis of data from several different geological problems, and to the Naval Ordnance Laboratory, Picatinny Arsenal, and National Institutes of Health in the design of experiments and the analysis of data.

The first draft of a manual on experimental statistics, being prepared under the sponsorship of the Office of Ordnance Research, neared completion. The final version will appear in the Army Ordnance Engineering Design Handbook Series.

Technical assistance was given to Diamond Ordnance Fuze Laboratory on tracking problems of the Mohawk River Project, to the Bureau of Aeronautics on a digital direct-reporting system for the Naval Air Test Center, Patuxent, Md., and on the dynamics of a jet engine. In addition, members of the staff were asked to make a survey of data processing facilities applicable to air traffic control for the Curtis Committee on Aviation Facilities Planning, for submission to the President and to Congressional leaders.

Technical advice and assistance in problem analysis, formulation of machine-performance requirements, and evaluation of system proposals were also provided to the Treasury Department in connection with the mechanization of the issue and redemption of savings bonds, and to the government of Puerto Rico for a general business management application. Similar technical consulting services have been provided to Highway Research Board, Automotive Safety Foundation, and Bureau of

Public Roads, in connection with traffic analysis, and to several Government agencies relative to information retrieval problems. A number of machine systems have been investigated for the Chemical Corps, U. S. Army, and a contract was placed for a new data-processing system at Fort Detrick.

Services to Other Government Agencies. In addition to the many activities described above, the Bureau is frequently called upon by other agencies of Government for assistance in solving a great variety of problems. This arises from the Bureau's broad research program in all areas of the physical sciences, as well as from its particular competence and facilities in certain fields. The following examples indicate the range and scope of these activities and are not intended to be inclusive.

The Adjutant General's Office was given assistance in the design and calibration of a new device for testing night vision. The Air Force was advised on methods of standardization of color, and color tolerances for the Air Force Academy uniform. At the request of the State Department and the National Science Foundation, a "nuclear clock" exhibit was designed for the U. S. Pavilion at the Brussels World Fair of 1958. The remote control system for monitoring radiation, developed earlier at NBS, was converted to cover a frequency range more adaptable to telephone line transmission, for use by the Atomic Energy Commission in tests being conducted in Nevada. In cooperation with the Public Health Service, assistance was given the Taft Sanitary Engineering Center in a complete inventory of industrial pollutants in the Louisville, Kentucky, area. The Quartermaster Corps was assisted in the selection of the proper type of adhesive for a variety of uses such as furniture, cold, and foul-weather clothing. The Frankford Arsenal was aided in the selection of several plastics to be used in the making of parts for a new binocular. Two articles, Leather Research in the USA, and Quality Control in the Leather Industry, were prepared for the State Department and Bureau of Foreign Commerce for distribution at a meeting of the Economic Commission for Asia and the Far East, to be held in Madras, India. Two representatives of the Agriculture Department were given assistance in the use and application of various instruments for testing textiles.

A special report has been prepared for the National Academy of Sciences Committee for the International Geophysical Year on the preservation of IGY records. IGY's record-keeping problem is rather unusual; it will receive scientific data from many countries, on papers of varied types and qualities. These must be preserved for many years, and some may be frequently handled by scientists consulting them. As the data will often be irreplaceable, the records must be stored with great care. The Bureau's report considers papers, inks, and bindings, outlines precautionary measures and storage conditions, and provides an extensive bibliography to facilitate the choice of preservation methods in different climates.

5. Appendixes

5.1. Organization of the National Bureau of Standards*

ALLEN V. ASTIN, *Director*

Associate Director for Chemistry
WALLACE R. BRODE

Associate Director for Physics
ROBERT D. HUNTOON

Associate Director for Engineering
A. T. MCPHERSON

Associate Director for Planning
NICHOLAS E. GOLOVIN

Assistant Director for Administration
R. S. WALLEIGH

Director Emeritus
LYMAN J. BRIGGS

SCIENTIFIC AND TECHNICAL DIVISIONS AND SECTIONS

ELECTRICITY AND ELECTRONICS, F. B. SILSBEE, *Chief*

Resistance and Reactance, J. L. THOMAS
Electron Devices, C. P. MARSDEN, Jr.
Electrical Instruments, F. M. DEFANDORF
Magnetic Measurements, I. L. COOTER, Acting
Dielectrics, J. D. HOFFMAN
Engineering Electronics, G. SHAPIRO, Acting
Electronic Instrumentation, C. STANSBURY
Electrochemistry, W. J. HAMER

OPTICS AND METROLOGY, I. C. GARDNER, *Chief*

Photometry and Colorimetry, L. E. BARBROW
Optical Instruments, F. E. WASHER
Photographic Technology, R. DAVIS
Length, L. V. JUDSON
Engineering Metrology, I. H. FULLMER

HEAT, C. M. HERZFELD, *Chief*

Temperature Physics, J. F. SWINDELLS
Thermodynamics, C. W. BECKETT
Cryogenic Physics, R. P. HUDSON
Rheology, R. S. MARVIN
Engine Fuels, F. L. HOWARD
Free Radicals Research, H. P. BROIDA

ATOMIC AND RADIATION PHYSICS, L. S. TAYLOR, *Chief*

Atomic Physics Laboratory

Spectroscopy, W. F. MEGGERS
Radiometry, E. K. PLYLER
Mass Spectrometry, F. L. MOHLER
Solid State Physics, H. P. R. FREDERIKSE
Electron Physics, L. L. MARTON
Atomic Physics, L. M. BRANSCOMB

*As of September 1, 1957.

Radiation Physics Laboratory, H. O. Wyckoff, *Chief*

Neutron Physics, R. S. Caswell
Nuclear Physics, U. Fano
Radioactivity, W. B. Mann
X-rays, H. O. Wyckoff
Betatron, H. W. Koch
Nucleonic Instrumentation. L. Costrell
Radiological Equipment, S. W. Smith
Radiation Instruments Branch, Atomic Energy Commission, R. W. Johnston

CHEMISTRY, E. Wichers, *Chief*

Organic Coatings, P. T. Howard
Surface Chemistry, W. W. Walton
Organic Chemistry, H. S. Isbell
Analytical Chemistry, H. A. Bright
Inorganic Chemistry, R. Gilchrist
Electrodeposition, A. Brenner
Molecular Structure and Properties of Gases, Floyd Buckley
Physical Chemistry, R. G. Bates
Thermochemistry, E. J. Prosen
Spectrochemistry, B. F. Scribner
Pure Substances, C. P. Saylor

MECHANICS, W. Ramberg, *Chief*

Sound, R. K. Cook
Mechanical Instruments, E. C. Lloyd
Fluid Mechanics, G. B. Schubauer
Engineering Mechanics, B. L. Wilson
Mass and Scale, H. H. Russell, Acting
Capacity, Density, and Fluid Meters, H. S. Bean
Combustion Controls, F. R. Caldwell

ORGANIC AND FIBROUS MATERIALS, G. M. Kline, *Chief*

Rubber, L. A. Wood
Textiles, W. D. Appel
Paper, R. B. Horrs
Leather, J. R. Kanagy
Testing and Specifications, R. D. Stiehler
Polymer Structure, N. Bekkedahl
Organic Plastics, F. W. Reinhart
Dental Research, W. T. Sweeney

METALLURGY, J. I. Hoffman, *Chief*

Thermal Metallurgy, T. G. Digges
Chemical Metallurgy, L. L. Wyman
Mechanical Metallurgy, J. A. Bennett
Corrosion, G. A. Ellinger
Metal Physics, L. M. Kushner

MINERAL PRODUCTS, I. C. Schoonover, *Chief*

Engineering Ceramics, M. D. Burdick
Glass, C. H. Hahner
Refractories, S. Zerfoss
Enameled Metals, W. N. Harrison
Concreting Materials, R. L. Blaine
Constitution and Microstructure, H. F. McMurdie

BUILDING TECHNOLOGY, D. E. Parsons, *Chief*

Structural Engineering, D. Watstein
Fire Protection, A. F. Robertson
Air Conditioning, Heating, and Refrigeration, P. R. Achenbach
Floor, Roof, and Wall Coverings, H. R. Snoke
Codes and Specifications, J. A. Dickinson
Heat Transfer, H. E. Robinson

APPLIED MATHEMATICS, E. W. Cannon, *Chief*

Numerical Analysis, J. Todd
Computation, M. Abramowitz
Statistical Engineering, C. Eisenhart
Mathematical Physics, R. F. Dressler

DATA PROCESSING SYSTEMS, S. N. Alexander, *Chief*

SEAC Engineering Group, P. D. Shupe, Jr.
Components and Techniques, R. D. Elbourn
Digital Circuitry, S. Greenwald
Digital Systems, A. L. Liener
Analog Systems, H. K. Skramstad
Application Engineering, S. N. Alexander (Acting)

OFFICE OF WEIGHTS AND MEASURES, W. S. Bussey, *Chief*

OFFICE OF BASIC INSTRUMENTATION, W. A. Wildhack, *Chief*

OFFICE OF TECHNICAL INFORMATION, W. R. Tilley, *Chief*

ADMINISTRATIVE DIVISIONS

Accounting, P. R. McClenon
Personnel, G. R. Porter
Administrative Services, H. P. Dalzell
Shops, F. P. Brown
Supply, G. B. Kefover
Management Planning, Ivan Asay
Budget, N. L. Christeller
Plant, H. Graham

BOULDER LABORATORIES, F. W. Brown, *Director*
Boulder, Colorado

CRYOGENIC ENGINEERING, R. B. Scott, *Chief*

Assistant Chief, B. W. Birmingham
Cryogenic Equipment, R. B. Jacobs
Cryogenic Processes, B. W. Birmingham
Properties of Materials, R. J. Corruccini
Gas Liquefaction, V. J. Johnson

RADIO PROPAGATION PHYSICS, R. J. Slutz, *Chief*

Upper Atmosphere Research, T. N. Gautier
Ionospheric Research, R. C. Kirby
Regular Propagation Services, W. B. Chadwick
Sun Earth Relationships, A. H. Shapley

RADIO PROPAGATION ENGINEERING. K. A. Norton, *Chief*

Data Reduction Instrumentation, W. E. Johnson
Modulation Systems, A. D. Watt
Navigation Systems, G. Hefley
Radio Noise, W. Q. Crichlow
Tropospheric Measurements, C. F. Peterson
Tropospheric Analysis, P. L. Rice
Radio Systems Application Engineering, R. S. Kirby

RADIO STANDARDS, W. D. George, *Acting Chief*

Asst. Chief for Radio Frequencies, W. D. George
Asst. Chief for Microwave Frequencies, D. M. Kerns
High Frequency Electrical Standards, M. C. Selby
Radio Broadcast Service, A. H. Morgan
High Frequency Impedance Standards, J. L. Dalke
Calibration Center, H. W. Lance
Microwave Physics, D. M. Kerns
Microwave Circuit Standards, R. W. Beatty

ADMINISTRATIVE DIVISION, S. W. J. Welch

NATIONAL BUREAU OF STANDARDS FIELD ESTABLISHMENTS

Lamp Inspector, Brookline 46, Mass.
Visual Landing Aids Field Lab., Arcata, Calif.
Master Railway Track Scale Depot, Clearing, Ill.

Materials Testing Laboratories
Allentown, Pa.
Denver, Colo.
San Francisco, Calif.
Seattle, Wash.

Cheyenne Mt. Field Station, Colorado Springs, Colo.
Radio Transmitting Station WWV, Beltsville, Md.

Radio Propagation Field Stations
Anchorage, Alaska
Barrow, Alaska
Carthage, Ill.
Fort Belvoir, Va
Gunbarrell Hill, Longmont, Colo.
Havanna, Ill.
Margarita, Panama Canal Zone
San Juan, Puerto Rico
Sterling, Virginia

Radio Noise Recording Stations
Bill, Wyoming
Front Royal, Va.
Kauai, Hawaii

5.2. Fiscal Data on NBS Program

PROGRAM AND SOURCE OF FINANCING	Obligations Incurred (in thousands of dollars)		
SUPPORTED BY NBS APPROPRIATIONS			
Operating Program:			
Expenses		$8,387	
Construction and Facilities Programs:			
Plant and Equipment	$1,012		
Construction of Laboratories	18		
Construction of Facilities	593		
		1,623	
Total, NBS Appropriations			$10,010
SUPPORTED BY OTHER FUNDS			
Research and Development Programs:			
Department of Defense and AEC	12,228		
Other Agencies	2,849		
Non-Governmental Sources	132		
		15,209	
Calibrations and Standard Samples		1,483	
Reimbursable Administrative Services		1,309	
Total, Supported by Other Funds			18,001
Total Program			28,011

5.3. Advisory Committees

STATUTORY VISITING COMMITTEE

[Reports annually to Secretary of Commerce on NBS activities (Dates indicate expiration of appointment.)]

DR. M. J. KELLY, President, Bell Telephone Laboratories, Inc. (1957)
DR. CLYDE E. WILLIAMS, President, Battelle Memorial Institute (1958)
DR. CRAWFORD H. GREENEWALT, President, E. I. du Pont de Nemours & Co. (1959)
DR. DETLEV W. BRONK, President, National Academy of Sciences (1960)
PROFESSOR F. SEITZ, University of Illinois (1961)

Technical Advisory Committees

[Designated by leading scientific and technical societies to advise NBS Director in specific technical areas. Members listed served during fiscal year 1957.]

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

DR. RALPH BOWN, Maplewood, N. J.
DR. C. G. SUITS, General Electric Company
DEAN F. E. TERMAN, Stanford University
DR. E. W. ENGSTROM, Radio Corporation of America
MR. ROBERT C. SPRAGUE, Sprague Electric Company
DR. J. A. HUTCHESON, Westinghouse Electric Corporation

INSTITUTE OF RADIO ENGINEERS

Professor Henry G. Booker, Cornell University
Mr. Stuart L. Bailey, Jansky & Bailey
Dean William L. Everitt, University of Illinois
Professor A. H. Waynick, Pennsylvania State University
Professor J. B. Wiesner, Massachusetts Institute of Technology
Dr. H. W. Wells, Carnegie Institution of Washington

AMERICAN INSTITUTE OF PHYSICS

Professor F. Seitz, University of Illinois
Professor D. M. Dennison, University of Michigan
Professor J. A. Bearden, Johns Hopkins University
Dr. M. Deutsch, Massachusetts Institute of Technology
Professor R. B. Lindsay, Brown University
Dean R. A. Sawyer, University of Mighigan
Professor Cecil T. Lane, Yale University
Professor Mark W. Zemansky, City College of New York
Professor A. O. C. Nier, University of Minnesota
Dr. H. M. Parker, General Electric Company
Dr. Otto Oldenberg, Harvard University
Professor John Strong, Johns Hopkins University
Professor Henry A. Fairbank, Yale University

POLICY COMMITTEE FOR MATHEMATICS

Dean Mina Rees, Hunter College
Professor Philip M. Morse, Massachusetts Institute of Technology
Professor David Blackwell, University of California
Professor A. H. Taub, University of Illinois
Professor Mark Kac, Cornell University
Dr. E. U. Condon, Washington University

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

Dr. Walter A. Dean, Aluminum Company of America
Dr. Earle E. Schumacher, Bell Telephone Laboratories
Dr. Maxwell Gensamer, Columbia University
Mr. Clarence E. Sims, Battelle Memorial Institute
Dr. E. C. Smith, Republic Steel Corporation
Dr. Cyril S. Smith, University of Chicago

AMERICAN CHEMICAL SOCIETY

Professor N. Howell Furman, Princeton University
Professor C. S. Marvel, University of Illinois
Dr. Milton Harris, Harris Research Laboratories
Dr. J. R. Ruhoff, Mallinckrodt Chemical Works
Dr. Norman A. Shepard, Stamford, Conn.
Professor Farrington Daniels, University of Wisconsin

AMERICAN CERAMIC SOCIETY

Dean Elburt Osburn, Pennsylvania State University
Mr. Wayne Deringer, A. O. Smith Corporation
Dr. A. C. Siefert, Owens-Corning Glass Corporation
Mr. Paul V. Johnson, Structural Clay Products Research Foundation
Mr. Harry W. Thiemecke, Homer Laughlin China Company
Mr. Hubert Woods, Portland Cement Association
Mr. H. N. Kraner, Bethlehem Steel Company

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Mr. James W. Parker, Ann Arbor, Michigan
Professor Dana Young, Yale University
Professor S. R. Beitler, Ohio State University
Professor C. Harold Berry, Harvard University
Mr. Paul V. Miller, Taft Pierce Manufacturing Company
Mr. Chalmer G. Kirkbride, Sun Oil Company

NATIONAL CONFERENCE ON WEIGHTS AND MEASURES

Mr. John P. McBride, Director of Standards and Necessaries of Life, Boston, Mass.
Mr. Charles M. Fuller, Sealer of Weights and Measures, Los Angeles, California
Mr. Harry J. Kennedy, Continental Oil Company
Mr. Seth T. Shaw, Safeway Stores, Inc.
Mr. C. J. McCaffrey, Ralph N. Brodie Company, Inc.
Mr. W. A. Scheurer, Exact Weight Scale Company

AMERICAN SOCIETY OF CIVIL ENGINEERS

Dr. G. H. Hickox, Engineer Research and Development Laboratories, Fort Belvoir, Va.
Dr. A. T. Ippen, Massachusetts Institute of Technology
Mr. Raymond C. Reese, Toledo, Ohio

AMERICAN STANDARDS ASSOCIATION

Mr. H. Thomas Hallowell, Jr., Standard Pressed Steel Company
Mr. John R. Townsend, Sandia Corporation
Mr. Arthur S. Johnson, American Mutual Liability Insurance Company
Vice Admiral G. F. Hussey, Jr., USN (Ret), American Standards Association
Mr. Cyril Ainsworth, American Standards Association

AMERICAN SOCIETY FOR TESTING MATERIALS

Mr. R. A. Schatzel, Rome Cable Corporation
Dr. A. Allan Bates, Portland Cement Association
Mr. T. A. Boyd, General Motors Corporation
Mr. Aiken W. Fisher, Fisher Scientific Company
Mr. R. E. Peterson, Westinghouse Research Laboratories

5.4. Awards and Honors

Recognition of the Bureau's contributions to science and technology often takes the form of awards and honors from academic, industrial, and professional groups. The following list reflects such recognition bestowed on Bureau staff members during the fiscal year 1957.

RECIPIENT	HONOR	SOURCE
Alexander, S. N.	Awarded Medal	Royal Academy of Engineering Sciences, Stockholm, Sweden.
Appel, W. D.	Harold Dewitt Smith Memorial Award	American Society for Testing Materials Committee D-13 on Textiles.
Branscomb, Dr. Lewis M.	Rockefeller Public Service Award	Administered by Princeton University as a national trust.
Carrington, Dr. Tucker.	Awarded Fellowship	NAS–NRC–NBS.
Cooter, Irving L. and Mundy, Robert E.	Third Prize for Paper	Washington, D. C., Section of AIEE.
Crandall, James R.	Elected to Fellow	American Ceramic Society.
Deitz, Victor	Awarded Fellowship	John Simon Guggenheim Memorial Foundation.
Eiseman, John H.	Award of Merit	American Gas Association.
Goldberg, Karl	Awarded Fellowship (Predoctoral)	National Science Foundation.
Green, Melville S.	Awarded Fellowship	John Simon Guggenheim Memorial Foundation.
Greenough, Maurice L.	Fulbright Fellow Outstanding Contribution Award.	Department of State, Washington Academy of Sciences.
Judd, Deane B.	Godlove Award	Inter-Society Color Council.
Lamb, V. A. and Young, J. P.	Award on Paper	American Electroplaters' Society.
Mann, David E.	Awarded Fellowship	John Simon Guggenheim Memorial Foundation.

RECIPIENT	HONOR	SOURCE
Park, John H. and Cones, Harold N.	Fulbright Fellow First Prize for Paper	Department of State, Washington, D. C., Section of AIEE.
Piccerelli, Dr. Robert T.	Awarded Fellowship	NAS–NRC–NBS.
Ramberg, Walter and Irwin, L. K.	Richard L. Templin Award	American Society for Testing Materials.
Reinhart, Frank W.	Award of Merit	American Society for Testing Materials.
Rodney, William S.	Awarded Fellowship	John Simon Guggenheim Memorial Foundation.
Teele, Ray P.	Elected Associate Member	Institute of Traffic Engineers.
Wall, Leo A.	Arthur S. Flemming Award	Junior Chamber of Commerce of Washington.
Washer, Francis E.	Talbert Abrams Award	American Society of Photogrammetry.

DEPARTMENT OF COMMERCE AWARDS

Coiner, Alfred S.	Meritorious Service Award	Personnel.
Corliss, Edith L. R.	Meritorious Service Award	Audiometry and Speech Analysis.
Dauses, August B.	Meritorious Service Award	Instrument Fabrication.
Deitz, Victor R.	Meritorious Service Award	Adsorption.
Geil, Glenn W.	Meritorious Service Award	Metallurgy.
Hahner, Clarence H.	Meritorious Service Award	Optical Glass.
Heald, Roy H.	Meritorious Service Award	Missile Aerodynamics.
Hudson, Ralph P.	Meritorious Service Award	Low Temperature Thermometry.
Kleinschmidt, Lawrence R.	Meritorious Service Award	Bituminous Technology.
Lang, Stewart M.	Meritorious Service Award	Phase Equilibria and Oxide Ceramics.
Madorsky, Samuel L.	Meritorious Service Award	Polymers.
Mandel, John	Meritorious Service Award	Applied Statistics.
Mandelkern, Leo	Meritorious Service Award	Polymers.
McMurdie, Howard F.	Meritorious Service Award	Crystal Chemistry.
Meggers, Edith R.	Meritorious Service Award	Editorial Services.
Projector, Theodore H.	Meritorious Service Award	Aircraft Lighting Equipment.
Reinhart, Frank W.	Meritorious Service Award	Plastics.
Robinson, Edgar L.	Meritorious Service Award	Engineering Metrology.
Smith, W. Harold	Meritorious Service Award	Organic Chemistry.
Bates, Roger G.	Exceptional Service Award	Hydrogen-ion Measurement.
Eisenhart, Churchill	Exceptional Service Award	Statistical Development.
Fano, Uco	Exceptional Service Award	Radiation Theory and Measurement.
Jessup, Ralph S.	Exceptional Service Award	Combustion Calorimetry Benzoic Acid Standards, and Fluorine Measurement.
FOSDIC Group: Greenough, M. L. Cook, Herbert D. Martens, Melvin Palasky, Ervin C.	Exceptional Service Award	Information Handling Equipment.
Nuclear Alignment Task Group: Ambler, Ernest Hayward, Raymond W. Hoppes, Dale D. Hudson, Ralph P.	Exceptional Service Award	Electron Emission from Aligned Nuclei.

5.5. The National Conference on Weights and Measures—Its Organization and Procedure*

Sponsored by the National Bureau of Standards

1. Objectives

The objectives of the National Conference on Weights and Measures are (a) to provide a national forum for the discussion of all questions related to weights and measures administration as carried on by regulatory officers of the States, Commonwealths, Territories, and Possessions of the United States, their political subdivisions, and the District of Columbia; (b) to develop a consensus on model weights and measures laws and regulations, specifications and tolerances for commercially-used weighing and measuring devices, and testing, enforcement, and administrative procedures; (c) to encourage and promote uniformity of requirements and methods among weights and measures jurisdictions; and (d) to foster cooperation among weights and measures officers themselves and between them and all of the many manufacturing, industrial, business, and consumer interests affected by their official activities.

*Statement formalized and approved by the Conference at its Forty-Second Meeting, June 1957.

2. Relationship With the National Bureau of Standards

The basic relationship between the National Bureau of Standards and the National Conference on Weights and Measures is sponsorship by the National Bureau of Standards of a means for the promotion of uniformity among the States in the complex of laws, regulations, methods, and testing equipment that comprises regulatory control by the States of commercial weighing and measuring. (This sponsorship is exercised under authority of that portion of the organic Federal Act under which the Bureau is authorized to undertake "cooperation with the States in securing uniformity in weights and measures laws and methods of inspection.")

Within the limitations of the funds available, the National Bureau of Standards assists the Conference by supplying technical information, guidance, and secretarial services, to the end that the Conference may operate effectively, constructively, and with fairness toward all affected interests.

Within the limitations of applicable Federal authorization and policy, the National Bureau of Standards publishes and distributes reports of the proceedings of the meetings of the Conference, reports of Conference committees, and model laws, regulations, specifications, and tolerances adopted by the Conference.

In exercising its cooperation with the Conference, the National Bureau of Standards acts primarily through the Office of the Director and specifically through the Office of Weights and Measures.

3. Constituent Membership

Membership in the Conference is of three classes, active, advisory, and associate.

Active membership is limited to weights and measures officers actively engaged in regulatory service and in the employ of States, Commonwealths, Territories, and Possessions of the United States and their political subdivisions, and the District of Columbia.

Advisory membership comprises representatives of agencies of the Federal Government who are concerned in any way with regulatory weights and measures officers or their official activities or who are interested in the objectives and activities of the Conference.

Associate membership comprises representatives of manufacturers, industry, business, consumers, and other persons, who are interested in the objectives and activities of the Conference.

Active, advisory, and associate membership is on an annual basis and is effectuated through registration at a meeting of the Conference and, in the case of active and associate members, payment of the currently prescribed registration fee.

Members of all classes have the privilege of the floor at meetings of the Conference.

4. Officers

The Director of the National Bureau of Standards and the Chief of the Office of Weights and Measures of the Bureau of Standards are, *ex officio*, the President and the Secretary, respectively.

A conference Chairman, four Conference vice-chairmen, a Treasurer, and a Chaplain are elected from the active membership, their terms of office running from the adjournment of the meeting at which they are elected through the succeeding meeting.

5. Committees

The annual committees are a Nominating Committee of seven members, a Resolutions Committee of seven members, and an Auditing Committee of three members. appointed by the Conference Chairman from the active membership, and an Executive Committee consisting of all the officers, *ex officio*, and ten members elected from the active membership. The committees appointed by the Chairman serve during his term of office. The term of the Executive Committee runs from the adjournment of the meeting at which its members are elected through the succeeding meeting.

The standing committees are the Committee on Specifications and Tolerances, the Committee on Laws and Regulations, and the Committee on Education, each with a normal complement of five members appointed by the President from the active membership on a rotating basis for five-year terms (one new member being appointed, and one old member retiring, each year), except when the appointment is to fill a vacancy caused by the death, resignation, or retirement from active service of a committee member, in which case the appointment is for the unexpired portion of such member's term. Each standing committee annually selects one of its members to serve as its chairman. At his option, the President may designate one or more advisory or associate members as consultants to a standing committee.

Special committees are appointed by the President from the active, advisory, or associate membership, in any combination deemed appropriate, as the need arises or the Conference requests. The life of a special committee is fixed as a definite period, not to exceed two years. At the expiration of the fixed period the committee ceases to exist, except that the life of a committee appointed to serve for one year only may, by action of the Conference, be extended for one year. If it is found necessary to establish a new special committee to carry on the activities of a committee so dissolved, the appointments are so made that the personnel of the new committee includes at least two persons who did not serve on the precedent committee. At his option, the President may designate the Conference Secretary as consultant or nonvoting secretary or both to a special committee.

6. Duties of Officers

The President addresses each meeting of the Conference, normally at the opening session, presenting matters of interest to the body and suggesting areas of discussion and study, and makes appointments to standing and special committees.

The Conference Chairman is the principal presiding officer at meetings of the Conference and of the Executive Committee, and makes appointments to the nominating, resolutions, and auditing committees.

The Conference vice-chairmen assist the Conference Chairman in the discharge of his duties, serving as directed by him.

The Secretary acts as secretary and executive officer of the executive committee and as nonvoting secretary to each standing committee, handles all details in connection with the arrangements for and the programs of the meetings, keeps the record of the proceedings of the meetings, and certifies to the Treasurer the correctness of bills rendered to the Conference for payment.

The Treasurer receives and accounts for all monies collected as registration fees, and pays all Conference bills certified by the Secretary as correct.

The Chaplain performs the duties customarily attendant upon that office.

7. Duties and Fields of Operation of Committees

The Nominating Committee annually presents a nonexclusive slate of nominees for all elective offices and for the ten elective memberships on the executive committee.

The Resolutions Committee annually presents for Conference action such resolutions as it has been directed by the Conference to prepare, and such additional resolutions as are deemed appropriate by the committee.

The Auditing Committee annually audits the books of the Treasurer and reports its findings to the Conference.

The Executive Committee reviews the general activities of the Conference and its committees, makes such recommendations to the Conference, the Conference officers, and the committee chairmen as it deems appropriate, advises with the Secretary with respect to the programs for the meetings, may at its option fill any vacancy in an elective office caused by death, resignation, or retirement from active service, and selects the dates and headquarters for the meetings. In the interim between successive meetings of the Conference, the Executive Committee acts for the Conference in any emergency situations that may arise.

The Committee on Specifications and Tolerances annually presents a report for Conference action. Its field of operation embraces all matters dealing with (a) specifications, tolerances, regulations, and requirements of any kind, relating to commercial scales, weights, measures, and weighing and measuring devices and accessories, including interpretation of such material whenever necessary, (b) standards and testing equipment for weights and measures officials, and (c) procedures for testing commercial equipment.

The Committee on Laws and Regulations annually presents a report for Conference action. Its field of operation embraces all matters dealing with model laws, model regulations, bills introduced for legislative enactment, methods of sale of commodities, and general and administrative provisions, relating to weights and measures supervision in general, but exclusive of such matters as are within the jurisdiction of the Committee on Specifications and Tolerances.

The Committee on Education annually presents a report for Conference action. Its field of operation embraces all matters dealing with the technical training and education of weights and measures officials, the education along weights and measures lines of the general public and of the users of weighing and measuring devices, and the public relations programs and procedures for weights and measures organizations, but exclusive of such matters as are within the jurisdiction of the Committee on Specifications and Tolerances.

8. Voting

All questions before a meeting of the Conference are decided by majority vote of those active members present and voting.

9. Procedures

The Conference officers and committees observe in all of their procedures the principles of due process—the protection of the rights and interests of affected parties; specifically, they (a) give reasonable advance notice of contemplated committee studies, items to be considered for committee action, and tentative or definite recommendations for Conference action, for the information of all parties at interest, and (b) provide that all interested parties have an opportunity to be heard by committees and by the Conference.

10. Changes in Organization and Procedure

Proposals for changes in organization or procedure of the Conference are not acted upon until the meeting of the Conference following the meeting at which such proposal is made.

11. Parliamentary Procedure

Issues on parliamentary procedure are resolved according to Roberts Rules of Order.

5.6. Publications

Publications in the Bureau's Series

Journal of Research. Complete scientific reports of the Bureau's research and development, both experimental and theoretical, in physics, chemistry, engineering, and mathematics, and the results of test and instrumentation activities in these fields are printed in the *Journal.* The subject matter of the reports embraces the fields of electricity and electronics, optics and metrology, heat, atomic and radiation physics, chemistry, mechanics, organic and fibrous materials, metallurgy, mineral products, building technology, applied mathematics, data processing systems, basic instrumentation, weights and measures, cryogenic engineering and radio propagation. (Annual subscription: domestic, $4.00; $1.25 additional for foreign mailing.)

Volume 57, July–December 1956

2687. Mixed path ground wave propagation: 1. Short distances. James R. Wait.
2688. Effect of object frequency on focal position of four photographic objectives. Fred W. Rosberry.
2689. An examination of the 1955 helium vapor-pressure scales of temperature. E. Ambler and R. P. Hudson.
2690. Heats of formation of xonotlite, hillebrandite, and foshagite. Edwin S. Newman.
2691. Effect of camera tipping on the location of the principal point. Francis E. Washer.
2692. Mass spectra of some lead alkyls. Edith I. Quinn, Vernon H. Dibeler, and Fred L. Mohler.
2693. Frequency response of second-order systems with combined coulomb and viscous damping. Thomas A. Perls and Emile S. Sherrard.
2694. Thermal properties of aluminum oxide from 0° to 1,200° K. George T. Furukawa, Thomas B. Douglas, Robert E. McCoskey, and Defoe C. Ginnings.
2695. Stress-strain relationships in yarns subjected to rapid impact loading: 4. Transverse impact tests. Jack C. Smith, Frank L. McCrackin, Herbert F. Schiefer, Walter K. Stone, and Kathryn M. Towne.
2696. Thermal expansion of polytetrafluoroethylene (Teflon) from −190° to +300° C. Richard K. Kirby.
2697. Preparation of D-arabinose-5-C^{14} from D-glucose-6-C^{14}. Horace S. Isbell, Nancy B. Holt, and Harriet L. Frush.
2698. Thermal expansion of binary alkali silicate glasses. Herman F. Shermer.
2699. Investigation of an alternating-current bridge for the measurement of core losses in ferromagnetic materials at high flux densities. Irvin L. Cooter and William P. Harris.
2700. Ionization and dissociation of the trifluoromethyl halides by electron impact. Vernon H. Dibeler, Robert M. Reese, and Fred L. Mohler.
2701. Techniques in high-resolution coincidence counting. George H. Minton.
2702. Chemical activity of gamma-irradiated polymethyl methacrylate. Leo A. Wall and Daniel W. Brown.
2703. Purification of substances by a process of freezing and fractional melting under equilibrium conditions. Augustus R. Glasgow, Jr., and Gaylon Ross.
2704. A high-voltage pulse generator and tests on an improved deflecting system of a cold-cathode oscillograph. Harold N. Cones.
2705. Dissociation constant of piperidinium ion from 0° to 50° C and related thermodynamic quantities. Roger G. Bates and Vincent E. Bower.

2706. Color evaluation in the cane sugar industry. Victor R. Deitz.
2707. System for classification of structurally related carbohydrates. Horace S. Isbell.
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Patents

(The following U. S. Patents have been granted to NBS inventors. Assigned to the United States of America, as represented by the Secretary of the Department noted in parentheses.)

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